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DESIGN FOR PRODUCTION MANUAL

VOLUME 1 OF 3

CONCEPTS

FINAL REPORT

PREPARED BY:

BETHLEHEM STEEL CORPORATION
SPARROWS POINT YARD

AND

A&P APPLIEDORE LIMITED
NEWCASTLE ENGLAND

AND

J. J. HENRY CO., INC.
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DESIGN PRODUCTION INTEGRATION

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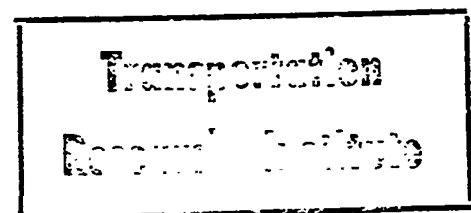
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ENCLOSURE (1)

FOREWORD

This manual is the final report of a project managed and cost shared by Newport News Shipbuilding for the National Shipbuilding Research Program under Maritime Administration contract DTMA91-82-C-20018. The program is a cooperative effort of the Maritime Administration's Office of Advanced Ship Development and Technology and the United States shipbuilding industry. Industry direction was provided by the Society of Naval Architects and Marine Engineers' Ship Production Committee Panel SP-4, Design Production Integration.

Principle research was conducted by Bethlehem Steel Corporation, Sparrows Point Yard who enlisted the services of A&P Appledore Limited, Newcastle-upon-Tyne, UK and J. J. Henry Company, Incorporated of Moorestown, New Jersey.

Project development demanded industry participation to insure that the manual respond to a need, that potential users were identified and that basic manual coverage was defined. Formal questionnaires were used in the early stages supplemented by telephone contacts and twelve face-to-face follow up meetings on the east, west and gulf coasts. As the need, potential user and basic content were confirmed, it became apparent that, for best results, industry should be involved in determining the manual structure and content. This was accomplished via development workshops on the east and west coasts and in the Great Lakes area. Forty eight individuals from 20 organizations participated. Shipyards from large to small were represented as were design agents and the Maritime Administration. Finally, to avoid duplication of effort and to benefit from as many responsible sources of input as reasonably possible, liaison was established with the Society of Naval Architects and Marine Engineers' Ship Design Committee.

Care has been taken to blend the needs, wants and advice of many into an orderly and authoritative work on efficient ship design and production. It is intended that users take advantage of the loose leaf format to make the manual even more useful by expanding it with their own implementing procedures.

VOLUME 1 - CONCEPTS

SYNOPSIS

Part 1 - Introduction to DESIGN FOR PRODUCTION MANUAL. The first chapter of this part describes the phasing and objectives of the whole DESIGN FOR PRODUCTION MANUAL project. The contents and function of the manual are outlined and its potential users identified. The structure of the manual and the chapter numbering system are explained to show readers how to find quickly what they want.

The next two chapters discuss the subject of productivity and attempt to answer the question, in which direction should management attention be focused in order to significantly improve productivity? They conclude that the implementation of design for production will make a considerable contribution to improving productivity.

The last two chapters discuss how changes in production technology have led to the need for changes in the way the technical offices carry out their function, and how design and production should work more closely together. Finally, the implementation of design for production is discussed.

Part 2 - Shipbuilding Policy Development. The first chapter of this part identifies the basic concepts around which the traditional method of shipbuilding was developed and demonstrates how the progressive use of assembly and welding methods led to the need for a new shipbuilding policy, that is, a new approach to the organization of both the technical and production functions.

Chapter 2 establishes the framework for the new shipbuilding policy and Chapter 3 discusses the development and implementation of that policy.

The "build" strategy is the application of the shipbuilding policy to a particular contract. In the climate of change now being experienced, a structured and documented approach is recommended. Chapter 4, describes how the build strategy document should be developed.

"The Design for Production Manual"

An Executive Summary

Many, many years ago, some wise caveman invented the wheel. It is more than likely that the first wheel was delivered late and over budget! Some things in the past millions of years have not changed. Maybe it is now time for change.

The manual that follows this summary is not a re-invention of the wheel. Some of the ideas presented herein may strike a familiar note as you read through the manual. The developers of the manual attempted to collect and assemble a multitude of ideas and techniques involved with shipbuilding; all having the common directive of Design/Production Integration. Their intent, however, was not only to collect these ideas but to also present them in such a manner as to assist you and your organization in a re-thinking process concerning shipbuilding design and production.

To this end, the writers want to emphasize that this manual is not a common cure for all of the U.S. Shipbuilding Industry's woes. It is merely presented to you as, hopefully, the catalyst to initiate the required re-thinking process and to give some information to you concerning the most effective starting points as to where this re-thinking effort should be directed.

The most logical way to summarize a piece of work having the magnitude of the manual is to try to clearly define its title 'Design for Production'. A possible definition of the manual and its objective could be "Designing to reduce production costs to a minimum, compatible with the requirements of the vessel to fulfill its intended function with acceptable reliability and efficiency". It is readily ascertainable that this definition protects the interests of the shipowner but also states the desired interests of the shipbuilder. Historically, the shipowner was primarily interested in those aspects of his vessel that most affected his dollar. Items such as vessel speed, fuel consumption, cargo carrying and handling capabilities and mission requirements were paramount in the owner's thinking. A private design agent **would** be hired to protect the owner's interests as listed above and the design developed around these interests led to an expensive, difficult to build, but functionally correct vessel. By the time the shipbuilder received the design, he would find himself tied to a design, more often than not, totally unsuitable for the production personnel, techniques and facilities available at the building yard.

It is apparent, or it should definitely be apparent, that high productivity shipbuilding is critically dependent on the effectiveness of the relationship between the shipbuilder and the ship designer. Their intertwined efforts should constantly strive to optimize the design processes, planning processes, production techniques and facilities available.

Ever so slowly, the situation is changing. There have been advances in construction techniques and shipbuilding facilities have been modernized. However, vessels are still being designed that do not utilize effectively these new techniques and facilities. This is the underlying problem. The design function is still ignorant of the needs of production and the production function is not knowledgeable of the design process. Shipyards are designing vessels around the use of pre-outfitted modules but ignoring the building basin crane capacity to lift the completed modules. Units are being designed utilizing plates of a given length ignoring the fact that the panel shop can operate more efficiently using plates of another length. Both of these examples must sound very academic; however, as shipbuilders and designers, we know that these types of design problems do, in fact, take place in our shipbuilding world.

Again recalling the definition of 'Design for Production' given earlier and realizing that problems as described in the previous paragraph do take place, we, as members of the domestic shipbuilding industry should remember that the uppermost objective of the shipbuilder should be to reduce production costs This is where our profits come from and also where they are lost.

The expansion of the design process to include a "Design for Production" function should have as its foremost objectives:

- ° To produce a design which represents an acceptable compromise between the needs of a shipowner and a shipbuilder. (Functionability versus Producibility)
- ° To produce a design which has features compatible with known characteristics of the shipyard's facilities. (Availability versus Producibility)
- ° To produce a design which facilitates the integration of the outfitting effort with the structural steel fabrication and assembly effort. (Integrability versus Producibility)

For all of this to work, the designer has to be familiar with production and the producer has to be familiar with the design function. To state the obvious, it will not be possible to achieve short delivery times and high productivity levels unless design and production work 'hand in hand'. After review of the manual, you will see that this idea is the common thread throughout the manual.

All U.S. shipyards are, in some fashion, moving along the Design/Production Integration Highway. Some have gone far and done well while others have stalled. The objective of the manual is to clearly show the way forward. The road is long and does have hazards but the final destination is clearly defined. That final goal is a vigorous and competitive U.S. Shipbuilding Industry.

VOLUME 1

CONCEPTS

PART 1

INTRODUCTION TO DESIGN FOR PRODUCTION

1.1 INTRODUCTION TO DESIGN FOR PRODUCTIONContentsPage No.

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1.1.2	The Productivity Gap - U.S. and Overseas	1-1/201
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1.1.1 OBJECTIVES OF THE DESIGN FOR PRODUCTION MANUAL

The first section of this chapter outlines the function of the manual. The second section explains the background to its production and sets out its objectives. The third section outlines the content of each of the three volumes of the manual and the fourth explains the structure and numbering system of the manual.

1.1.1.1 Function of the Manual - Although this manual may be used by itself, it should not be regarded as the definitive work in this field. It is limited to explaining concepts, translating these to practical applications, and providing guidelines to assist in achieving effective implementation. However, it is important to emphasize that it is balanced and "stand-alone."

The manual will be most effective as a developing tool, in the sense that it will act as a catalyst in the development and implementation of design for production and also in that it will be dynamic and will expand in detail and scope in logical stages in the future. Furthermore, using the techniques described, **users will be** able to develop their own documentation covering processes, methods, facilities, and other areas of operations.

The manual is structured to allow ready access to particular topics. From the viewpoint of the individual user, each topic is self-contained to simplify the use of the manual in the shipyard or designer's office. In addition, sections may be readily separated for use in different parts of the organization.

For the shipyard, when placed in the context of overall business plans, the manual will be used to develop and implement a new shipbuilding policy.

For the design agent, specific ship production information will necessarily come from the shipyards who build to the agent's design. The manual will show how the designer can incorporate that information, and why it is important to do so. It will also provide a basis for the development of a set of producible design standards.

The manual is aimed not only at designers, planners, production engineers, and those responsible for improving design/production integration, but at everyone involved in the shipbuilding process.

Principal Users

- o managers responsible for implementation
- o design engineers
- o planners
- o production engineers

PRINCIPAL USERS

- MANAGERS RESPONSIBLE FOR IMPLEMENTATION
- DESIGN ENGINEERS
- PLANNERS
- PRODUCTION ENGINEERS

1.1.1.2 Background - The project has been conducted in phases covering the definition of the requirements for the manual and the actual production of the manual. The objective of the first phase was to answer such questions as:

- o What are the needs and practices of the industry with regard to Design/Production integration?
- o **Is** there a need for a Design for Production Manual?
- o Who would be the users of the Manual?
- o What would be the scope and content of the Manual?
- o Who could participate effectively in the development of a Manual?

To determine the answers to these questions, we distributed questionnaires to a selection of shipyards and design agents. This selection included all yards classified as "large" and a limited number of small yards and design agents. The questionnaires were followed up with a series of presentation and discussion meetings at various locations around the country. The responses to the questionnaires and the opinions expressed at the meetings were jointly analyzed and the conclusions and recommendations were given in the Phase 1 Report.

DESIGN FOR PRODUCTION MANUAL

PROJECT PHASES

I DEFINITION OF REQUIREMENTS

II PRODUCTION OF MANUAL

III DISSEMINATION TO INDUSTRY

Phase 1 answered these questions and identified a number of problem areas which a manual would go a significant way towards solving. These included:

- o The need for a more standard and documented approach to the design process.
- o The need to develop the interim product concept for input to the design process.
- o The need to define production criteria to guide the engineer during all stages of the design process.
- o The need to document process and methods information.
- o The need to document facility constraints information.
- o The need to improve communications between ship-yards and design agents, particularly with regard to the integration of design and production requirements.
- o The need to increase awareness of producibility techniques and of how to handle and when to inject production requirements into the design process.

Although good design for production applications will vary from yard to yard, depending mainly on vessel type and size, there was found to be a clear need to set down in manual form the concepts of design for production, well-illustrated and with a range of practical examples. However, the manual goes further than providing a communication function, it also includes guidelines for the implementation and development of design for production.

A wide range of potential users was identified. The principal users were identified as the managers responsible for implementation, design engineers, planners and production engineers.

The content and format of this Design for Production Manual are the result of this definition phase.

Design for Production Manual project phases

- I Definition of Requirements
- II **Production** of Manual
- III Dissemination to Industry

1.1.1.3 Contents of the Manual - The manual is divided into three volumes:

- o VOLUME 1 - CONCEPTS: Why is Design for Production necessary?
- o VOLUME 2 - DESIGN/PRODUCTION INTEGRATION: What is Design for Production?
- o VOLUME 3 - APPLICATION OF PRODUCTION ENGINEERING: HOW is Design for Production applied?

VOLUME 1 - Concepts introduces the user to the subject of "design for production." PART 1 emphasizes and measures its effect on productivity. It also includes the definition, principles, objectives and organizational requirements of design for production and its supporting functions. PART 2 traces the development of shipbuilding and explains the need for a new approach to the organization of the technical and production functions. It defines the elements of the new approach and provides a framework for the development of both shipbuilding policy and contract build strategy. The Appendix defines a number of terms used in the manual.

VOLUME 2 - Design/Production Integration aims, as the title suggests, to show the way to improve the integration of design and production. The main purpose of Part 1 is to explain the need for the formalization of the approach to and documentation of design and production processes and procedures. Part 2 concentrates on the design stages and producibility criteria and on requirements at each stage. It also looks at the format and production of engineering information. Part 3 discusses ship production technology and suggests how and what information should be documented to assist in the implementation of design for production. Part 4 examines and explains the role of planning and how it interacts with the design, production engineering, and production functions. The Appendix defines a number of terms used in the manual.

VOLUME 3 - The Application of Production Engineering shows how to improve the quality and how to extend the application of production engineering. Part 1 introduces and explains the concepts and key techniques of production engineering applicable to shipbuilding. Part 2 addresses the application of production engineering at the highest level and translates concepts to practical examples. Part 3 and establishes rules and gives examples of product subdivision and interim product definition. It also takes a practical look at production stages, identification coding and organization of work. Part 4 gives an approach to solving day-to-day production engineering problems with a number of detailed examples in both steelwork and outfitting. The Appendix defines a number of terms used in the manual.

Although the manual demonstrates logical sequence and development of ideas, it is not intended to be read as a narrative. Rather, each chapter may be used as a reference by an individual engaged in a particular design, planning, or production engineering task. See Section 1.1.1.4 for an explanation of how the manual is structured and it most easily might be used. Cross-references are given to help readers find related information quickly.

DESIGN FOR PRODUCTION MANUAL

CONCEPTS

Introduction to Design for Production

Shipbuilding

Policy

Development

DESIGN PRODUCTION INTEGRATION

Requirements

Ship Design Stages

Ship Production

PLanning

APPLICATIONS

Product (on Engineering Concepts

Ship Geometry and Layout Engineering

Shipbuilding Policy

Detailed production Engineering Applications

1.1.1.4 Using the Manual -The manual is bound into **three** volumes. Each volume is divided into a number of parts. Each part has a number of chapters and each chapter a number of sections.

The list of contents of the whole manual is given by volume, part and chapter at the front of each volume. Also at the front of each volume is a series of short synopses of each part within that volume. These synopses cue the reader as to which parts should be referenced in the study or application of a particular topic. There is also a synopsis at the beginning of each chapter, together with a list of the most important cross-references to other chapters of the manual. These may refer to essential preliminaries, to related subjects, or to more detailed examples. To enable more detailed study of some topics, a bibliography is appended to certain sections. A glossary of *terms* used concludes each volume.

A four-digit numbering system has been used to identify the various volumes, parts, chapters, and sections:

The first digit is the number of the volume.

The second digit is the number of the part.

The third digit is the number of the chapter.

The fourth digit is the number of the section.

Thus, the first chapter of Part 2 of Volume 3 is numbered 3.2.1 and the first section of that chapter is numbered 3.2.1.1. Similarly, with regard to the page numbering system, the first two digits refer to the volume and part number, respectively. The last three digits indicate the number of the chapter and the page within that chapter. Thus page 2-3/117 is the seventeenth page of Chapter 1 of Part 3 of Volume 2.

Illustrations and drawings are incorporated in the text at the appropriate point (rather than being collected together at the end of sections) and are page numbered.

1.1.2 THE PRODUCTIVITY GAP - U.S. AND OVERSEAS

This chapter discusses the productivity gap between US and overseas shipyards. It examines the various factors which affect labor productivity and attempts to answer the question, Which direction should management attention be focused in order to significantly improve productivity?

CROSS-REFERENCES

1.1.3 Improving Productivity through Design for Production

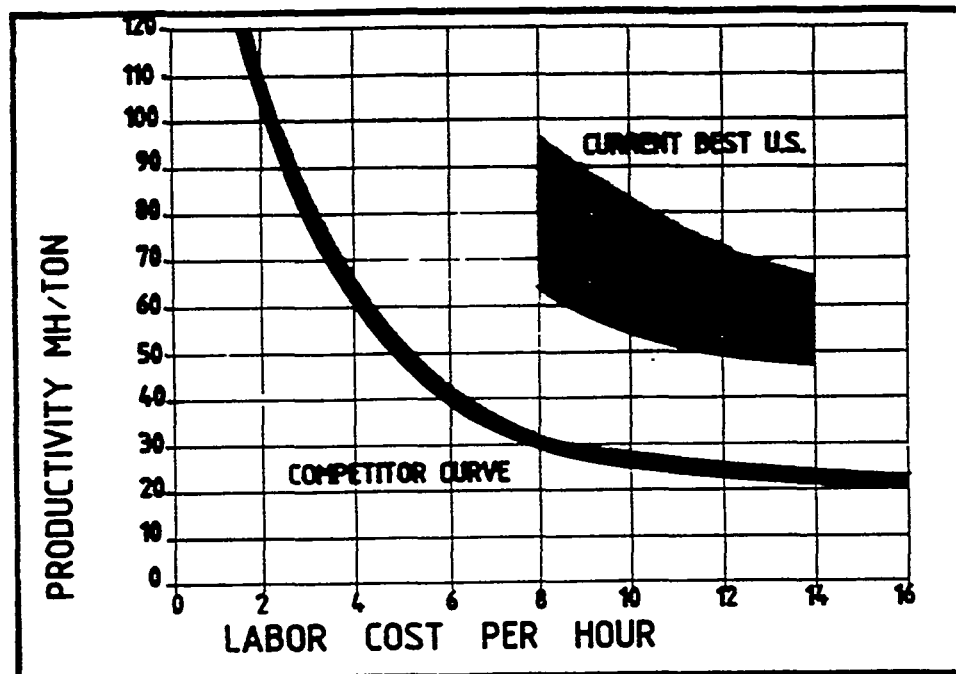
1.1.2.1 Competitiveness and Cost - Many factors determine the competitive position of a shipyard. One of the most significant, of course, is the cost of production, which includes materials, labor and overhead costs. One area of cost particularly under the control of shipyard management is the application of manpower. While the unit cost of labor is influenced by external factors, the productivity of labor is very much influenced and controlled by internal factors - in particular the ability of the management of the company.

Shipbuilders are well aware of the relationship between productivity and prospective earning power, and thus are constantly searching for ways to improve productivity. They focus on cost-effective improvements which also increase profitability.

1.1.2.2 The Productivity Gap - For the same vessel type and size, Japanese and certain Scandinavian yards will use only one third to one half of the hours and take less than half the time to construct the vessel as compared to many yards in the United States. A recent study, which measured the gap between typical U.S. yards and a number of good foreign yards, supports this statistic and is shown on Table 1 in Chapter 1.1.3.

Whatever one believes regarding the existence or otherwise of productivity differences, there is no doubt about the existence of cost differences. The figure on page 1-1/203 shows a line of constant low cost per ton which links those shipbuilders who are internationally competitive. Countries with shipyards on the "competitive curve" include:

THE PRODUCTIVITY GAP



- o South Korea, with low labor cost and relatively low productivity.
- o Japan, with higher labor costs and good productivity.
- o Sweden and Denmark, with high labor costs and in some cases the best productivity.

Most other countries lie above the line, thus creating a productivity gap. Unit labor costs will not fall, except in a few rare cases, and one of the few ways for established shipbuilders to move towards the competitor curve is to improve manpower productivity. Of course the Koreans and Japanese are actively working to open the gap, that is, to improve their own production. Furthermore, new, low labor cost nations are emerging to join the international shipbuilding league.

But in which direction should management focus attention in order to significantly improve labor productivity?

Although available comparative data relate to commercial shipbuilding projects, it is reasonable to assume that a similar gap exists for naval ships. Even where no direct competitive situation exists, the implicit "gap" would indicate that significant cost-saving opportunities are being ignored.

1.1.2.3 Factors which Affect Productivity - Shipyard managers have tended to believe that certain factors dominate the achievement of high productivity. Included in these are:

- o facilities
- o planning **and** control systems
- o attitude of unionized labor

Facilities - Will capital investment guarantee improved productivity? Consider the situation around the world:

- o Japanese and Scandinavian yards have made huge investments in facilities and are among the most efficient world shipbuilders.
- o The Koreans have also invested heavily, but Korean yards are not on top of the productivity league.
- o Significant capital has been invested in the United Kingdom. these yards which have the best facilities are among the most efficient in the United Kingdom, but are well behind the best in the world.

Sadly, there are many examples of shipyards throughout the world where substantial sums of money have been spent on facility improvements but where little or no payback has been achieved. Good facilities are indeed an element in the productivity equation, but it is not possible to become efficient by capital investment alone.

Planning and Control Systems - Can the implementation of sophisticated computer systems lead to improved productivity? Again, consider the situation around the world: In Japan, investment in computer systems has not been as great as elsewhere in the world. Planning systems are simple and effective and Japanese shipbuilders have initially concentrated on computerized material control systems. European and U.S. yards lead the Japanese in the implementation of CAD/CAM systems. The Koreans have purchased and implemented sophisticated computer-based manufacturing control systems, but as previously stated, they are nowhere near the top of the productivity table. In the United Kingdom and elsewhere, many yards have made a substantial investment in both facilities and systems but still do not figure near the top of the productivity table.

Over the years in many shipbuilding nations and companies, planning as "weak sister" within the organization, with little to offer the "real shipbuilders." As a result, planning offices often become the dumping ground for the unwanted, hardly the environment from which to influence management policy-making. If managers identified the need for planning, they would attempt to set up a local planning organization to assist them. Invariably, these attempts failed as information did not flow to the embryo planning organization either in the required format or at the right time.

All "systems," including technical, purchasing, material control, production engineering, and planning, are interrelated and information must flow freely between them. The management of the company must understand this so that systems and procedures will be developed enabling users of information to receive the correct inputs at the appropriate time. Users can then carry out the processes required of them and in turn generate timely and relevant outputs.

Investment in systems is not the panacea for management in its efforts to improve productivity. **As** with facilities, it is an element but not the overriding influence on the route to improved productivity.

Labor Unions and Craft Demarcation - In many countries, management believes that union obstruction and lack of trade flexibility are major factors in holding back productivity improvement. There are exceptions, however: In the Far East, the labor force is not as regimented as the west widely believes; even in Japan, there are craft flexibility restrictions. Scandinavian unions are strong, but work with management, while in the United Kingdom, flexibility agreements have been negotiated although management has not yet taken full advantage of them.

Trade union attitudes and craft flexibility issues may create problems for management, and there are cases in which a large proportion of front-line management time is expended in trivial wrangles. With sufficient forethought and good communications, however, unions need not be a barrier to improved productivity.

Given that management cannot simply invest its way to improved productivity nor hide behind union problems, what is the key to unproved productivity? There are, in fact, many interrelated factors which affect productivity and there are five main headings under which the factors can be grouped. These are:

- o design for production
- o shipyard facilities
- o shipbuilding techniques
- o organization and systems
- o the workforce

These may be defined as follows:

Design for Production: The extent to which the vessel is designed for ease of production in a particular facility. This includes consideration of the structural breakdown and construction sequence; steel, outfit and engineering arrangements; production engineering, simplification, standardization and group technology; value engineering; standards application; and so on.

The Facilities: The physical arrangement, capability, capacity, and efficiency of each element of the production system.

Shipbuilding Techniques: The extent to which the best modern steelwork fabrication, outfit production, ship construction and outfit installation, materials handling, and storage methods are effectively applied within the physical constraints of the shipyard.

organization and Systems: The extent to which the best appropriate methods are effectively applied to the following activities: process and production planning, production of technical information; organization of work; production scheduling and *control*; purchasing and stores control; and quality and dimensional control, etc.

Workforce: Includes effective hours, incentives, job satisfaction: motivation, labor skill, working practices, safety and welfare, working conditions, and working environment. The valid premise is that an attitude which is supportive of constant improvement is essential to success.

All these factors have an influence on manpower productivity. However, the key to improved productivity can be generally stated to be management's ability to organize work and to provide the necessary supporting technical, production engineering, planning and material control systems in order to optimize facility and labor utilization.

The next chapter examines the magnitude of the difference in productivity between U.S. and overseas builders and, of particular relevance to this manual, considers how much of this difference may be due to poor design-for-production.

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1.1.3 IMPROVING PRODUCTIVITY THROUGH DESIGN FOR PRODUCTION

This chapter briefly discusses the measurement of productivity in overall terms and goes on to describe a recent study which measured the difference in productivity between U.S. and overseas shipyards. It then postulates how much of this difference is due to poor design for production in U.S. yards. Finally, it discusses the role of this manual in helping to close the productivity gap.

CROSS-REFERENCES

1.1.2 The Productivity Gap - U.S. and Overseas

1.1.4 Design/Production Integration

1.1.5 Design and Production Engineering

1.2.2 Basis for Shipbuilding Policy Development

3.1.1 Implications for the Main Shipyard Functions

1.1.3.1 Productivity Measurement - Shipping demand is normally measured in DWT, but to the shipbuilder gross registered tons (GRT) or compensated gross registered tons (CGRT) are more important estimates of shipbuilding capacity and output than DWT. In terms of shipyard employment and the value of work content, the CGRT concept is generally accepted as a "realistic" measurement of shipbuilding output. At best, the CGRT estimate of shipbuilding output (and the CGRT per employee estimate of shipbuilding productivity) is a compromise because of the variation in vessel construction methods, both between nations and within nations. It is an attempt to provide a common basis for international shipbuilding comparison by reducing data to a common denominator. In practice, a certain type and size of vessel is taken as unity, with which all other types and sizes are then correlated. The unity factor is derived from general cargo vessels of 10,000 dwt and over which are given the coefficient of 1.0. Compensated tonnage is obtained by multiplying gross tonnage by the required coefficients.

The coefficients have changed over time; the latest ones, those agreed by the Organization for Economic Cooperation and Development in February 1978, as shown on page 1-1/303.

The coefficients take little account of series production or indeed of the highly automated nature of some shipyards. Shipbuilding is a dynamically changing industry, continually substituting capital for labor with a significant variation the manhour content for identical vessels constructed in different yards. Further, taking a general cargo vessel as unity may not be appropriate when true regard is given to the product mix of the world's shipyards. Nevertheless, in the absence of any other adequate common denominator the concept of CGRT is the most suitable available at present. Its limited use lies in comparing and contrasting the outputs, orderbooks, and productivity of different shipyards and shipbuilding nations. To this end, it is accepted and widely used by such bodies as the Association of Western European Shipbuilders and Japan's Ministry of Transport.

COMPENSATED TONNAGE CO-EFFICIENTS FEBRUARY 1978

SHIP TYPES	CO-EFFICIENTS
<u>CRUDE OIL TANKERS</u>	
10- 30,000 DWT	0.65
30- 50,000 DWT	0.50
50- 80,000 DWT	0.45
80-160,000 DWT	0.40
160-250,000 DWT	0.35
250,000 DWT plus	0.30
<u>PRODUCT TANKERS</u>	
10-30,000 DWT	0.80
30-50,000 DWT	0.60
50,000 DWT plus	0.50
<u>DRY BULK CARRIERS</u>	
10-30,000 DWT	0.60
30-50,000 DWT	0.55
50-100,000 DWT	0.50
100,000 DWT plus	0.45
<u>COMBINED CARRIERS</u>	
10-30,000 DWT	0.65
30-50,000 DWT	0.55
50-100,000 DWT	0.50
100,000 DWT plus	0.45
<u>GENERAL CARGO SHIPS</u>	
4-10,000 DWT	1.40
10,000 DWT plus	1.00
<u>REEFERS</u>	
4-10,000 DWT	2.00
10,000 DWT plus	1.60
<u>FULL CONTAINER SHIP AND HIGH SPEED LINER</u>	
4-10,000 DWT	1.40
10-30,000 DWT	0.90
30,000 DWT plus	0.80

SHIP TYPES	CO-EFFICIENTS
<u>RO-RO'S AND CAR CARRIERS</u>	
4-10,000 DWT	2.00
10,000 DWT plus	1.60
<u>LPG AND CHEMICAL CARRIERS</u>	
4-10,000 DWT	1.60
10-30,000 DWT	1.00
30,000 DWT plus	0.90
<u>LNG CARRIERS</u>	
4-10,000 DWT	1.60
10-30,000 DWT	0.90
30-50,000 DWT	0.70
50,000 DWT plus	0.50
<u>SMALL VESSELS</u>	
<u>TANKERS AND BULK CARRIERS</u>	
Under 4,000 DWT	3.00
4-10,000 DWT	1.80
<u>OTHER DRY CARGO (ex. ferries)</u>	
Under 4,000 DWT	4.00
<u>MISCELLANEOUS</u>	
<u>FERRIES AND PASSENGER</u>	
All sizes	2.50
<u>OTHER NON-CARGO (inc. tugs, dredgers, fishing vessels etc)</u>	
Under 500 GRT	5.00
500-2,000 GRT	3.00
2,000 GRT plus	2.00

1.1.3.2 Comparative Productivity Study - In 1980, a productivity assessment study was undertaken in order to measure the difference in performance between typical U.S. commercial shipbuilders and good comparable foreign shipyards. The measure of productivity used was output per man in terms of compensated gross registered tons per employee per year. The study was carried out as follows.

A small number of major U.S. yards were selected from the 13 yards which were surveyed in the MarAd sponsored, 1978 Technology Survey. The ones selected were among the best of these yards which did little or no naval work. The reasons for this were, first, since the comparison was to be made with good foreign yards then good U.S. yards should be chosen, and secondly, the relatively unsophisticated bulk carriers which were the subject of the study should generally not be built in the shipyards currently specializing in highly sophisticated naval vessels.

Four good foreign yards were selected from the 16 yards with which the US yards were compared during the 1978 Technology Survey. In selecting the comparable foreign yards, the following principal selection criteria were **used**:

- o work experience (previous ten years and current)
- o maximum ship size
- o shipbuilding employment
- o size (acres)
- o type of shipyard (for example, new or redeveloped)

Ship completions for each yard for the four years 1976 - 1979 were obtained. These were tabulated in terms of ship type, deadweight, gross registered tons and compensated gross registered tons. The main source of information was Lloyd's Register of Shipping.

Manpower figures were obtained for each yard for the four years under consideration. The figures included labor and staff (direct and indirect) and, in the case of the Japanese yard, they included "outsideworkers" (that is, subcontract labor).

Productivity in terms of compensated gross registered tons per man per year was calculated for each yard.

It was found that there was considerable variation from year to year in each yard. There were two main reasons for this:

1. Conditions did not remain stable during the 1976 - 1979 period. Both output (in terms of ship type, size, and volume) and the size of the labor force changed significantly in most yards.
2. Work in progress **at each Year end and the completion of a ship** in December of one year as opposed to January of the following year made a measurable difference to the year's results.

It was found that the minimum period to consider in order to get a sufficiently reliable result was three years. Note that the results for the Japanese yard were adjusted to take account of the fact that working hours per man year in Japan were some 10% greater than in the U.S. and Western Europe.

The results of the study confirmed what is generally accepted in shipbuilding circles. That is, that productivity in the best Japanese **and Scandinavian** yards is of the order of 100% better than in good U.S. or U.K. shipyards. Thus, whereas a typical U.S. yard might be able to produce four medium sized ships per year, a similar foreign yard could produce of the order of eight ships per year with a labor force the size of the U.S. yard's.

The next part of the study determined what proportion of this difference was due to design for production and what was due to other factors. This was done by assigning "marks" to each of the shipyards according to their characteristics and performance under each of the following headings:

- o design for production
- o the facilities and shipbuilding technique
- o organization, systems, and the workforce

The results **were** consistent with the productivity measurements and it was therefore **possible** to separate the effects of each of the factors. The findings were as follows:

Design for production: About 30% of the difference in productivity between the typical U.S. yard and good foreign yards could be accounted for by superior design for production in the foreign yards.

The Facilities are Shipbuilding Techniques: About 35% of the difference **could** be accounted for by better facilities and their layout as well as by the application of superior shipbuilding techniques in the foreign yards.

Organization, Systems, and the workforce: About 35% of the difference could be accounted for by superior organization and systems and a more effective workforce found in the foreign shipyards.

while the study looked at a particular range of ships, it is believed that the results will generally apply to vessels of all classes and are valid today.

1.1.3.3 Closing the Productivity Gap - As previously stated, the key to improving productivity is the ability to organize work such that both facility and labor utilization are optimized. How is work organization to be improved? In the simplest design for production terms, the objective must be to STANDARDIZE, **SIMPLIFY**, and SPECIALIZE:

Increased STANDARDIZATION will lead to the identification of a limited range of interim products. SIMPLIFICATION of interim products will lead to reduced work content and easier production. This, in turn, will allow SPECIALIZATION through the establishment of work stations, each producing a limited variety of products with purpose-designed processes and equipment.

The need to achieve short build cycles creates further pressure for standardization, simplification, and specialization. The need to achieve good work organization requires a new approach to vessel design to satisfy the needs of production.

Good work organization is manifested in the shipyard by the following:

- o high utilization of working areas
- o high utilization of labor
- o clearly identified interim products
- o clearly identified work stations
- o clearly identified and packaged materials
- o relevant technical information
- o simple but effective planning systems
- o good housekeeping
- o high morale

Productive and well organized yards have clearly defined objectives and policies which provide a consistent framework for all company activities. They have a shipbuilding policy. Many companies need to develop a new policy, because either they do not exhibit the characteristics of good work organization or the characteristics of the highly productive yards or because they are losing their competitive edge. Shipbuilding objectives and policy are discussed in detail in Part 2 of this volume.

In summary, highly productive yards are characterized by clearly defined objectives and policy, short build cycles, overlapping of steel and outfit work, and management attention to factors like tons per square foot per month.

GOOD WORK ORGANIZATION

HIGH UTILIZATION OF WORKING AREAS
CLEARLY IDENTIFIED INTERIM PRODUCTS
CLEARLY IDENTIFIED WORKSTATIONS
IDENTIFIED AND PACKAGED MATERIALS
RELEVANT TECHNICAL INFORMATION
SIMPLE BUT EFFECTIVE PLANNING SYSTEMS
GOOD HOUSEKEEPING

HIGHLY PRODUCTIVE YARDS ARE CHARACTERIZED BY

- CLEARLY DEFINED OBJECTIVES AND POLICY
- SHORT BUILD CYCLES
- OVERLAPPING OF STEEL AND OUTFIT WORK
- MANAGEMENT ATTENTION TO FACTORS LIKE
TONS/FT²/SHIFT/MONTH

The **productivity** study in the previous section showed that there is much to be gained through the adoption of a new approach to vessel design to satisfy the needs of production. There is a clear need for improved design/production integration, and this manual necessarily concentrates on that **subject**. But it also covers other closely related elements which affect productivity and efficiency, such as planning, material control, production engineering, production technology, shipbuilding policy and so on. If this whole range of new technology is applied concurrently, then the shipyard will achieve that quantum leap forward in performance imperative to improve competitiveness and profitability.

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1. 1. 4 DESIGN/PRODUCTION INTEGRATION

This chapter discusses how changes in production technology have led to the need not only for the design and production functions to work more closely together, but also for changes in the way the engineering office carries out its function. This is followed by discussions on implementing design for production procedures and on the integration of design, material procurement, and production.

CROSS-REFERENCES

- 1. 1. 3 Improving Productivity Through Design for Production
- 1. 1. 5 Design and Production Engineering
- 1. 2. 1 Impact of Welding and Assembly Methods
- 1. 2. 2 Basis for Shipbuilding Policy Development
- 1. 2. 3 Implementation of Shipbuilding Policy
- 2. 1. 2 Productivity Objectives
- 2. 1. 1 Implications for Main Shipyard Functions
- 3. 1. 2 Production Engineering Decisions

1.1.4.1 The Need for Integration - The need for Design/Production integration arises from changes in the production system itself.

Traditionally, construction cycle times were long and the achievement of high throughputs were made **possible by** multiple-ship, simultaneous construction. Steel work preceded outfit work **and outfit** work was carried out almost entirely after the erection and launch of the steel hull.

With the introduction of new welding and assembly techniques the production system has changed. Production cycle times have become shorter as pressure from the market has dictated lower prices and faster delivery times. There is both an overlapping in time and a physical separation of steel and outfit assembly work. The change in production system has led to the need for a corresponding change in the technical system. The technical function must now provide information in a different timescale, sequence, and format..

One of the objectives of the new production technology is to separate steel and outfit assembly work as far as possible with the manufacture of large outfit assemblies away from steelwork. Outfit information is required earlier to enable these outfit assemblies to be manufactured. In addition, many minor steel and outfit items must be manufactured and installed much earlier. This is necessary because early completion of hot work will allow jobs such as painting to be integrated into the overall production process. The sequence and timing of technical work must therefore change significantly.

The need for people at the technical function end to understand production requirements and for production departments to understand technical procedures and requirements is greater than ever. It will not be possible to achieve the low production cycle times, short delivery times, and high productivity unless technical and production functions work closely together.

The traditional role of the ship designer is the preparation of an overall design of vessel which will have a performance satisfying the Owner's operational or functional requirements. The concept of design for production, however, requires that in satisfying these requirements, the ship designer must also give attention to ease of production. There are thus two major aspects to design: design for performance and design for production. There are other aspects also, including design for overhaul, repair, and maintenance, which will be considered later.

The overall objective of design for production can be defined as follows:

Design to reduce production costs to a minimum, compatible with the requirements of the vessel to fulfill its operational functions with acceptable reliability and efficiency.

Clearly, there will be areas of interaction and the role of the ship designer can be seen in this context as one of arbiter, having the ultimate responsibility of deciding whether performance or production considerations shall take precedence in any particular case or of deciding the nature of the compromise to be reached. The organization of the design agents and shipyards must allow a rational resolution of the interactions following full discussion and analysis.

Many of the procedures proposed in this manual involve consideration of every feature of the ship from an overall viewpoint. Any tendency to divide design into the traditional elements of steelwork, pipework, machinery, electrical, and so on, will result in an inadequate basis upon which to develop effective design for production. Consideration of the interrelationship between one element and another is essential; and the term Integrated Design is used to define this concept.

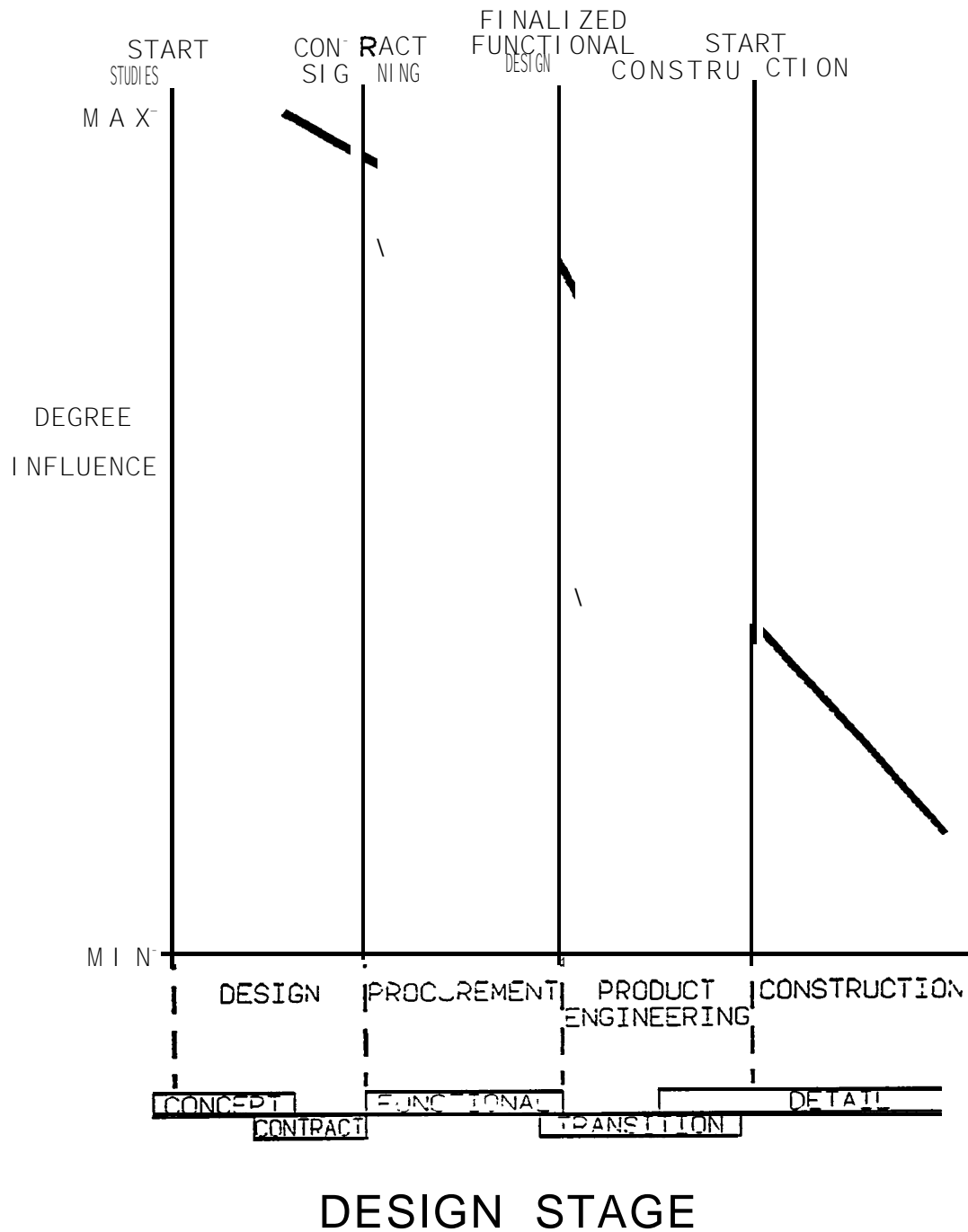
The extension of the design process to include a design for production function has the following primary objectives:

- o To produce a design which represents an acceptable compromise between the demands of performance and production and where appropriate takes into account the needs of overhaul, repair, and maintenance.
- o To ensure that all design features are compatible with known characteristics of the shipyard facilities.
- o To apply the individual design for production principles and procedures insofar as they are relevant to the particular vessel and to the particular shipyard where the vessel is to be built.
- o To coordinate the interrelationship between the machinery, electrical and outfitting work with the structural work, in order to create a fully integrated design.

It is vital, of course, that design for production effort start early in the design process. Designers have the greatest influence on the cost of the vessel during the earliest design stages when main materials and equipment and the basic configuration are being decided. The influence they have on cost drops off quite rapidly-in the later design stages as seen on page 1-1/405.

Design for production effort can achieve its greatest impact only if the company has developed a shipbuilding policy which is based on the "modern method of ship production." Part 2 of this volume gives a full explanation of the basis and development of shipbuilding policy. However, it is worthwhile at this point to give an outline of the scope and content of a company shipbuilding policy.

INFLUENCE ON COST



The objective in defining a company shipbuilding policy is to establish a "standard" approach to ship construction. This can be achieved through the following-step-by-step approach:

1. Develop a product work breakdown structure. This facet of the shipbuilding policy has a more significant effect on production efficiency than any other single aspect of shipbuilding construction, and is central to the concept of simple production requiring only simple planning.

The basic aim is to subdivide the ship into a narrow range of interim product types. Each product type may be identified by the sequence and nature of the operations involved in its manufacture and assembly. The aim is to design each ship in such a way that the narrowest possible range of product types are produced on a repetitive basis in the required numbers to complete the vessel. Furthermore, a conscious attempt is made to ensure that individual items of a specific product type contain, within practical limits, equal work content.

Products which are produced in relatively large numbers and relatively short cycle times are referred to as "on flow" items. Products of this type would be produced by facilities that have been purpose-designed. Products that are produced in relatively small numbers may be collected together and produced in areas specifically allocated to "off flow" work. "Off flow" work is characterized by being of variable work content and produced in relatively small numbers and in relatively longer cycle times than "on flow" work.

2. Establish the "ideal" ship construction method and sequence. Primary concerns would be optimize material sizes, subdivide hull into "ideal" erection units, develop "ideal" erection sequence, optimize advanced outfitting, reduce the overall construction cycle time, and identify special problems resulting from the latter.
3. Identify shortfalls in the capacity and capability of existing facilities to meet the requirements of the ideal construction method.

4. Determine the most appropriate suboptimum solution and draw up proposals for the eventual removal of the constraints identified in Step 2 above. These proposals would form the basis for a master plan for future facilities development.
5. Develop standard manufacturing methods and a standard list of operations for product type. Nonstandard operations would be done "off flow." An important aspect of the development of this concept is the part played by the designer in extending the proportion of "on flow" work in each ship as a part of the design strategy.
6. For each ship type and size to be constructed, determine the workload associated with each "on flow" type product. This information will be placed in the databank for planning resource requirements. With respect to potential overloads of "off flow" work, it is expected that there will be an active policy for subcontracting this work when necessary.
7. Identify work stations for the manufacture and assembly of each interim product type and, according to their projected workloads, determine relevant manning levels.
8. **Develop** standard methods for the fabrication and assembly of each interim product type. This would include a set of related operations lists. These standard methods must be documented and provided to the designer in order for the design function to be supportive to such standard methods.

Although these are dependable guidelines, shipbuilding policy, of course, must be dynamic and responsive to changes in technology, methods, and facilities.

1.1.4.2 Implementing Design for Production Procedures - All departments within the shipyard exist to support the production effort. Design and drawings offices are of particular importance because so many of the early decisions they take, irrevocably affect production activities.

Traditionally, draftspeople have been used to produce drawings which, in effect, are technical pictures, rather than being used to produce sets of working instructions. The need to provide specific work station information to the shop floor will be achieved only by a change of procedures within the technical office.

For some time leading shipyards in many parts of the world have subdivided contract cycle times in such a way as to allow an extended period prior to production for detailed design, planning, and production engineering activities. This has facilitated the development of design for production techniques and procedures. The short production cycle time characteristic of those shipyards requires a longer design lead time to carry out the necessary technical work; as a result, overall contract cycle times have not, until relatively recently, been significantly shorter. The extensive application of design of production has, however, now realized shorter lead times while still improving productivity.

Design for production is primarily concerned with designing work content out of the vessel and with improving the efficiency of production. The achievement of these objectives will in turn lead to higher labor and facility utilization and to shorter cycle times. High labor utilization and better use of the working day will come from improved work flow as interim products related directly to work stations are incorporated in the design in increasing numbers. Reduced cycle times will come from a reduction in work content and a ship breakdown geared to the yard's facilities.

Many design for production applications, particularly relating to geometry and block breakdown, do not of themselves affect lead time significantly, and a start may be made on their implementation even in cases of very short lead time. Other applications, for example outfit assembly techniques, do require an investment both in time and money to realize the potential benefits. In these cases, it will be necessary for each individual shipyard to review its own position and to define an implementation program.

In both cases, however, the implementation will in fact consist of two parallel yet interrelated processes.

1. Generalized experience and practice gained by systematically attempting to apply design for production principles by the ship designer on designs which are produced at the inquiry stage and may or may not be built. Experience can also be gained by looking at the published designs of production facilities in overseas yards. Visits by ship designers to overseas yards should incorporate a study of the extent to which the principles and procedures put forward in this manual have already been implemented.
2. Specific experience from ships actually built by the yard. This is gained by examining achievements and setbacks resulting from the application of new design for production ideas.

Experience gained on specific contracts can be added to the general body of experience if shipyards consciously decide to implement design for production in this way and if they involve all appropriate members of the technical and management team. Thus, design decisions may routinely combine the requirements of design for performance with those of production.

Lead time requirement is a product of the level of technology employed in the engineering office (for example, the extent of the use of computers) and the balance chosen within total contract cycle time between lead time and production time. In making the transition to longer lead times, the orderbook will be a dominant factor as continuity of ship production must be assured. This implies that the implementation of design for production procedures must be phased to suit each individual yard.

1.1.4.3 Earlier Material Specification - Shipbuilding differs from other manufacturing industries in that, in order to achieve high productivity, most of the material requirements must be established before the design of the vessel is finished. Many leading shipyards which have recognized the importance of the overlap between design and procurement are currently striving to become more competitive by achieving greater overlap, even for the variety of ships being constructed simultaneously. Their goal is to achieve complete integration between design, material procurement, and production.

Objectives of early material specification are:

- o to ensure early ordering of all materials,
- o to provide a parts database that will enable material control procedures to operate effectively, and
- o to provide a quantity survey of parts to be used for work content calculations.

The benefits to be gained may be summarized as follows:

- o Materials are available in the yard when required for production.
- o Materials can be organized to be in the right place at the right time, thus ensuring continuity of work and improved utilization of labor.
- o) Work packages with a balanced work content can be defined so as to enable better use to be made of production resources.

Not surprisingly, many shipyards have found that proper control of materials substantially facilitates control of labor.

Material specification includes listing of materials and their attributes in order to provide information to the procurement and production administration systems. Material takeoff procedures will operate at different levels of detail according to the stage of the contract, for example:

- o Long lead items will be defined either before the contract or early in the life of the contract.
- o Detailed material lists will be prepared from production drawings.

Since it is important to produce the material takeoff as early in the life of the contract as possible, purchase listings should be prepared directly from diagrammatic and classification drawings. Estimates of quantities can be refined later where necessary. As precise data become available, work packages of balanced work content can be defined. Work package material lists will then be used to coordinate and control the movement of materials on the shop floor.

It will be important that any material listing system has the ability to provide data sorted to suit user requirements, for example:

- o by block
- o by zone
- o by work package

Since work content estimation is likely to be based on physical attributes of material, that is, joint length, factorized pipes, paint area, etc, the potential for calculating work content at the same time as material takeoff can be realized.

In order to reduce the amount of lead time required, or alternatively, to make the best use of limited lead time available, it is essential to identify, specify, and order materials at the earliest time possible. Hence, many shipyards order at least 70% of all materials by-value at the basic design stage and continue to order materials through the functional and detail design stages. Initial material orders will obviously be made against ship system, but at later stages orders will be made against zone and eventually by work package.

A major organizational problem is to reconcile each stage of design and material ordering with its predecessor and to ensure that at the end of the process the parts and materials lists are identical to the end user's requirements. In order to solve the problem of manipulation and reconciliation, it is important that the chosen material code system facilitate performance of this task. Furthermore, the sheer numbers of items involved and the tedious nature of the work make this area a prime candidate for the introduction of a computer-based system to organize the shipbuilding process.

1. 1. 5 DESIGN AND PRODUCTION ENGINEERING

This chapter discusses design engineering and why a new approach to design and the production of work instructions is needed. Production engineering is defined and its role described. The last section of the chapter discusses the implementation of design for production.

CROSS-REFERENCES

- 1.1.4 Design/Production Integration
- 1.2.1 Impact of Welding and Assembly Methods
- 1.2.2 Basis for Shipbuilding Policy Development
- 1.2.3 Implementation of Shipbuilding Policy
- 2.1.2 Producibility Objectives
- 2.4.1 Structure and Organization of Planning
- 3.1.1 Implications for Main Shipyard Functions
- 3.1.2 Production Engineering Decisions

1.1.5.1 Design Engineering - The Need for a New Approach -
Throughout this manual, the design process is considered in five stages. These are defined as follows:

Conceptual Design: the establishment of overall features of the vessel to meet mission requirements.

Contract Design: the establishment of the features of the design sufficient to provide the basis of a contractual arrangement.

Functional Design: the establishment of the functional features of the design for the purpose of classification and other approval and complete material specification.

Transition Design: the translation of the features of the design from a system orientation necessary to establish functional performance to a planning unit orientation necessary to establish production requirements.

Detail Design: the establishment of the features of the design sufficient detail to allow local purchasing, part manufacturing and subsequent assembly and installation to be carried out.

Essential to the definition of design engineering procedures is the realization of two facts. The first of these is that modern shipbuilding practice requires that information aid work instructions correspond with each stage in the production process. Second, every ship can be regarded as a hierarchy of interim products; although each ship unique, many of the interim products are standard. This standardization shall be applied at the highest possible level as the physical constraints of the ship will allow.

Traditionally shipyard drawing offices developed the detail definition of a vessel by system, that is, steel systems, joiner systems, pipe systems, electrical systems, and so on. These drawings in terms of development, format, and content were approval-oriented and were descriptive of what the finished vessel would consist of, not how it would be produced. The use of this type of drawing for production purposes in an industry which, in recent years, has changed its production methodology from being system-oriented to being zone-by-stage-oriented has two dramatic effects. First, it is impossible to be consistent in production because interpretation of the methods and production information varies throughout the workforce and management. Second, establishing some form of consistent interpretation media in terms of either another technical department or additional responsibilities being allocated to existing departments is not a solution because:

- o it increases the number of staff and consequently overhead.
- o it increases the amount of duplication of information and reduces the efficiency of the production support departments.

The problem is not insurmountable, but the only remedy is reorganization of the technical offices and presentation of product-oriented information rather than system oriented information.

In order to develop and implement a new organization for the technical function and revised information flows and formats, there are a number of other systems, organization, and policy which must be established in parallel. These include:

- o A company shipbuilding policy.
- o Clearly defined production workstations which apply standard methods.
- o A comprehensive production control system in terms of planning, material control, work content estimation, manpower allocation, and recording.
- o Organization of the design and drawing offices into multidiscipline groups dedicated to the definition of the vessel by zone and stage.
- o Inclusion of loft work as part of the technical function.

- o A coding system which will identify parts and assemblies either uniquely, by ship standard, or by yard standard.
- o A well-defined data system which provides consistent references for all dimensional control during construction.

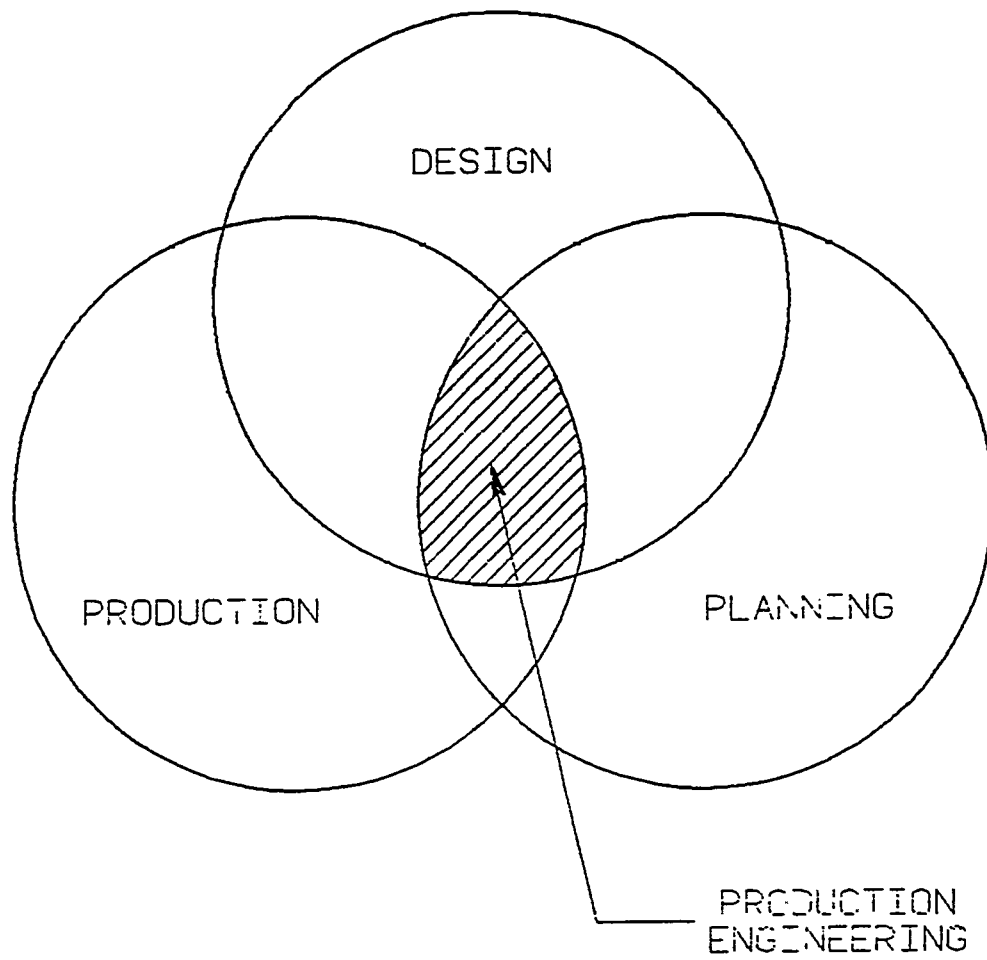
There are a number of general criteria which should be applied in the development of new technical office procedures. These would include that duplication of information and effort should be avoided wherever possible, and that drawings should be multipurpose, and production-oriented, and capable of being annotated or added to for other purposes, such as approval by regulatory bodies. In other words, technical effort needs organization just as the production effort does.

In order to promote new thinking in the design and drawing offices and to encourage change in the format and content of information, it may be necessary to avoid the use of the traditional drawing names. Drawing titles such as General Arrangement, Machinery Arrangement, Profile and Decks, etc, all carry implied format and content relating to traditional drawings which have not changed since the times of wooden ships.

The development of the definition of the product has five distinct areas which provide total product definition by production stage. These are:

- o allocation and arrangement of functional spaces
- o assembly identification and analysis
- o detail system definition by primary zone
- o process and sequence analysis
- o production definition by work stage

Note that these distinct areas are not strictly a sequence of events but are divisions of product definition development which require differing outputs in terms of information format and content. Each area is itself developed in hierarchical levels which correspond across the areas, to provide a comprehensive product definition by production stage. This subject is considered in detail in Volume 2 of the manual. The flow chart on page 1-1/505 shows the flows of information and the outputs to material procurement, tactical planning, and so on.



Production engineering as overlap of
design, planning, and Production.

In recent years both the range of ship types and the complexity of shipboard installations have increased dramatically. Concurrently there has been a move towards reducing the skill content of many tasks. In these circumstances it is no longer practical to rely solely on the experience based skills of craftsmen. It has become necessary to develop more formalized - processes for applying production engineering.

The main objectives of production engineering are as follows:

- o To assist production departments to achieve or improve upon targets and goals established in the shipbuilding policy.
- o To order and control decisions which will affect production manufacturing and assembly processes.
- o To monitor production technology developments in the industry.
- o To identify opportunities and to submit proposals for cost and time reductions in production processes.

It can be seen that production engineering is the by definition the function which builds bridges between departmental structures, although production engineering itself may not necessarily exist as an identifiable department. To achieve the objectives of production engineering it is realized that the scope ranges across many departments and disciplines, and if fully effective, will require the application of a wide variety of skills. The rationale for applying these skills to such a wide scope is to keep production costs to a practical minimum.

When production engineering techniques are applied during design development, a different approach is required from that which faces the production engineer with an existing design which might be impractical to produce. The main difference is that in the former situation there is no calculation of saving; the design is engineered to be low cost. In the latter situation, design changes have to be engineered to produce a cost benefit; otherwise there is no reason for changing the design. In the second case therefore the amount to be saved is a function of how bad the original design is from the producibility standpoint. The principal difference between these two approaches is the cost to engineering departments of work associated with redesign.

Production engineering may be an implicit or an explicit function. That is to say, it can be incorporated into the general engineering process, or design work may be reviewed by a separately created function. As an implicit function it is most cost-effective, but this requires that design engineers have the knowledge and ability to make decisions relating to production techniques, practices, and conditions. conversely, as an explicit function, it assumes that the production engineer will have design and production knowledge and experience, and has the ability to mediate between the functional requirements and the production requirements of the design. in either case the implications of production engineering can impact on shipyard operational costs, direct and indirect contract costs, capital expenditure, labor practices, and therefore profit.

Whether production engineering is an implicit or explicit function, we can, by collecting data related to production activities, lay out a set of standard references which can be used by designers and production engineers. Such documentation will include data on:

- o product range
- o shipbuilding policy
- o facility capability
- o production stages
- o work station operations
- o working practices
- o subcontract policy
- o standards

All of this documentation must be input and available to the technical department.

Production engineering operates broadly at three levels. Design-for-production is applied at all levels but perhaps more so at the tactical level. The levels are:

- o strategic or long term
- o tactical or medium term
- o detail or short term

Strategically, the production engineering function is concerned with the overall development of the company, with a time scale of perhaps five to ten years. Tactically, the function is concerned with contracts, and the time scale is related to contract timescales. The detailed production engineering function is concerned with short-term and immediate local problem-solving, although solutions may be incorporated in shipyard standards for future reference.

STRATEGIC

- o Shipbuilding Policy Development
- o Development of Standards
- o Facilities Development Planning
- o Preliminary Subdivision of New Products
- o Production Engineering Research and Development

TACTICAL

- o Contract Build Strategy
- o Product Subdivision
- o Assembly Analysis
- o Work Content Estimation
- o Production Methods Envelopment
- o Facilities Data Development

DETAIL

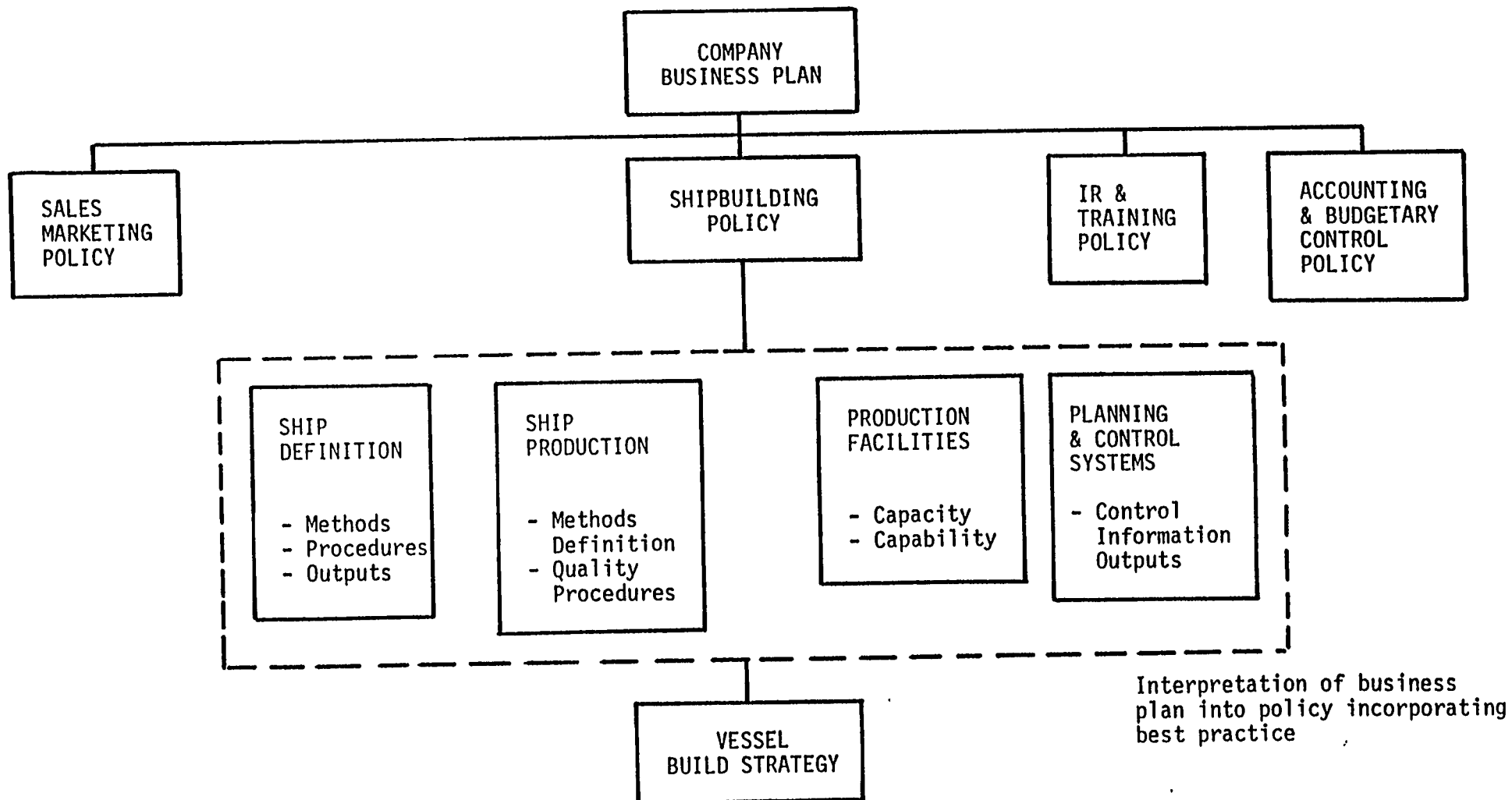
- o Production Engineering Support
- o Process Engineering
- o Production Engineering Feedback

1.1.5.3 Implementation of design for Production - The key to the implementation of design for production is the availability of information on production requirements and standards so that these can be incorporated into the design from the earliest stages. As we have stated earlier, the vehicle for achieving this is the company's stated and documented shipbuilding policy (see page 1-1/513).

This policy flows from a definition of the commercial objectives of the company and at the highest level is a statement of the volume of business which must be done to cover overhead and to generate required levels of profit. The profit mix and overall rate of throughput will lead to rates of throughput in each major production area. This in turn will lead to decisions on facilities development and subcontract policy to ensure that the output of ships to meet the commercial objective can be achieved.

At the next level of analysis, the vessels are subdivided into a hierarchy of interim products. The objective will be to rationalize and standardize these products across the range of ships in the company's portfolio. The next stage is to look at the interim products in the context of the shipyard facilities. Products and work stations must be brought together. Both product design and work station arrangements may be changed to improve the efficiency of manufacture and installation. Consequently, the design of the products and the definition of the work stations and their associated methods must enable production to consistently achieve the required cycle times and quality so that the overall objectives of the company can be met. Designers must thus be fully aware of the capabilities of all work stations.

While the ideal approach to the implementation of design for production is to set out to develop a new shipbuilding policy - and many companies have done this - a pragmatic alternative is to allow the policy to develop through the preparation of a series of contract build strategy documents.



Interpretation of business plan into policy incorporating best practice

Application of policy to particular contract

Shipbuilding policy and build strategy documents are both vital to design/production integration at the strategic level. Implementation at the tactical level relies on the capability of engineers to carry out process analysis, preparation of method descriptions and similar tasks. Implementation at the detail level relies on the appointment of staff or field engineers to form the link between production and technical functions.

For the design/production integration to be carried out effectively requires properly educated, trained, shop-floor-experienced people. In Japan and Scandinavia in particular, shipbuilders have had a clear policy for many years for the training and development of shipbuilding engineers. The U.S. shipbuilding industry as a whole now needs to reassess its approach to the training of shipbuilding engineers. Too many designers are in the position of having to make major design decisions having barely seen, let alone worked in a shipyard. And in many cases where shipyard-based technical people move to ship or production management, they do so at too high a level. In Japan and Scandinavia, the approach is from the bottom up, with well qualified young people getting direct shop floor experience.

An interim solution might be for individual shipyards to give young graduate naval architects and engineers early shop floor experience by using them in the role of field or staff engineers. Typically, a Staff engineer would work within a production area or workshop or on board and would be the interface between production and technical functions. A network of engineers communicating and providing feedback to all stages of design would make a significant contribution to design/production integration.

Finally, another major feature of the successful implementation of design for production is discipline. Before work starts, the whole manufacturing and construction process must be thought through and laid out in detail on paper. This preproduction effort will be largely wasted unless production has the discipline to follow the determined program, methods and procedures. Apart from the need for discipline, it is also clear that if production is to follow the "plan," then it must be fully involved in the thinking stages.

VOLUME 1

CONCEPTS

PART 2

SHIPBUILDING POLICY DEVELOPMENT

1.2 SHIPBUILDING POLICY DEVELOPMENT

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1.2.1 Impact of Welding and Assembly Methods	1-2/101
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1.2.4 Contract Build Strategy	1-2/401

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1.2.1 IMPACT OF WELDING AND ASSEMBLY METHODS

This chapter first identifies the basic concepts around which the traditional method of shipbuilding was developed. These concepts were well understood and successfully applied in many parts of the world prior to the widespread introduction of assembly methods into world shipbuilding.

The next section demonstrates how the progressive use of assembly and methods, first in steelworking and eventually in outfitting, created the need for an entirely new approach to the organization of both the technical and production functions. The new approach is necessary in order to establish effective control over the shipbuilding process and hence to achieve the productivity levels of the best international shipbuilders.

CROSS-REFERENCES

- 1.1.4 Design/Production Integration
- 1.1.5 Design and Production Engineering
- 1.2.2 Basis for Shipbuilding Policy Development
- 2.3.1 Modern Ship Production Technology
- 3.1.3 Standard Approach to Ship Construction

1.2.1.1 Traditional Shipbuilding Method - The transition from wooden to iron and eventually to steel ships was successful, despite the fact that the new materials had very different characteristics to those previously used. This success probably can be attributed to the fact that although the materials changed, basic construction strategy did not.

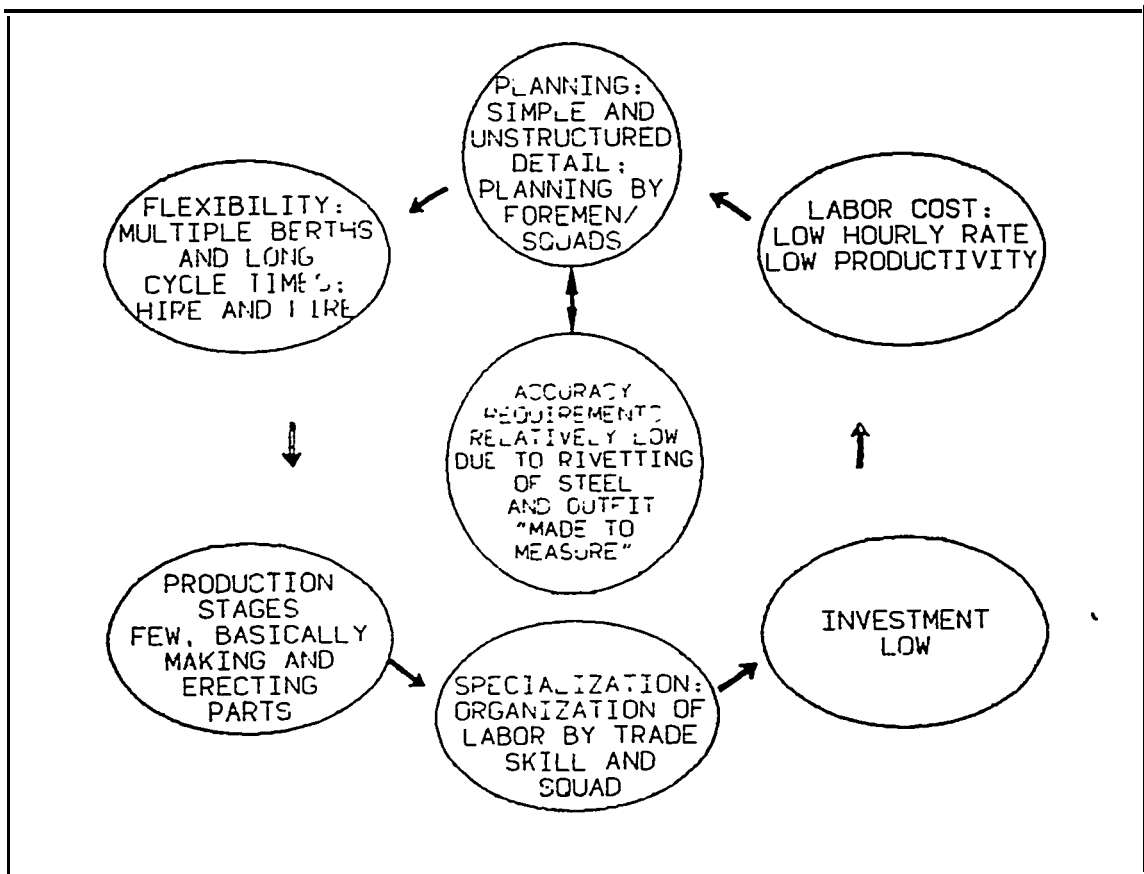
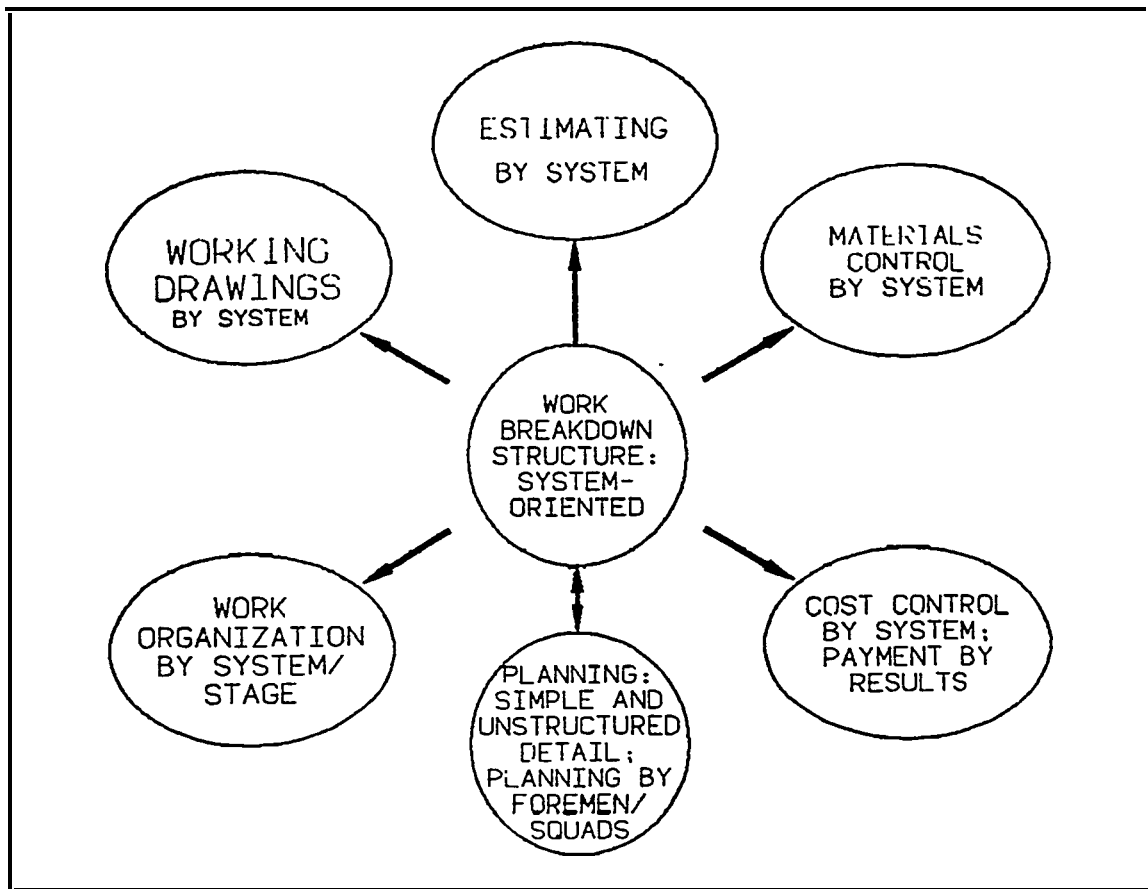
Early method of construction simply consisted of the erection and joining of parts to form a complete object, in this case a ship. Characteristically, this method of production involved relatively low levels of capital investment coupled with high levels of labor skills and usage.

On examination, the traditional method is seen to be founded on ten basic concepts which appear to be central to its successful development:

1. Clearly defined and unambiguous production stages. Basically, these were the marking/templating, making, erecting, fairing and joining of steel hull parts, and the lining off, drawing/templating, making, and installation of outfit parts.
2. Use of a consistent work breakdown structure. This was system-oriented, and when related to outfitting, self explanatory. In the case of steelwork, the hull was divided into what may be termed "structural systems" - frames, shell plating, deck plating, etc.
3. Efficient organization of work through the development of specialist "squads" each with clearly defined responsibilities expressed in terms of system/systems and work stage/stages. Thus, a shipfitter would be responsible for making and erecting steel parts and, if a member of the shell squad, would be responsible for work done relating to "shell system" parts.

4. Complete conformity of technical information with production methods. This was achieved by systems-oriented design and loft information, with steel drawings produced for framing, shell, etc, and outfit drawings produced for the individual piping systems, ventilation systems, etc. Even outfit steel drawings were "system-oriented" in that there were drawings for small hatches, ladders, walkways, rails, stanchions, etc.
5. Use of simple and unstructured planning and control systems: detailed planning was left solely to first line management. Control was essentially by system and trade group, with perhaps a shop/ship breakdown. The use of payment-by-results systems motivated workers to plan ahead to ensure satisfactory flows of information and materials, thus releasing management from much of its detail planning responsibilities.
6. System-oriented estimating, materials control, and cost control. This gave a relatively straightforward task in comparing actual with estimated costs for labor and materials.
7. Flexibility. The use of multiple berths and long cycle times gave squads a degree of flexibility within which they could organize their work. Also labor was shed as and when necessary to match the workload.
8. Specialization. Labor was organized by trade and skill level. Work was organized around key squads which allowed management to develop simple indicators with which to plan and monitor production in overall terms.
9. Low investment, low hourly wage rates and low productivity.
10. Relatively low accuracy requirements. This was due to the built-in flexibility of the primary joining method used, that is, riveting. Time to complete construction work could be determined with a high degree of probability since process time was less likely to be affected by small dimensional inaccuracies. Control was also exercised by the payment systems, under which workers were not paid for or unusable pieces.

The traditional method of shipbuilding was developed over a very long period and it is significant that several generations of shipbuilders used the same basic code structures, estimating data, standard drawing lists, planning data, and so on. These systems and work methods were not only the "flywheel" which sustained the traditional method of shipbuilding but also the heart of the resistance to change (see page 1-2/105).



Representation of how various aspects of traditional construction method interface.

1.2.1.2 Development of New Methods - The introduction of welding and assembly techniques started well before World War II. During the war these methods gained a real impetus and were highly developed particularly by the new specialist yards in the United States. However, this surge did not significantly affect traditional shipbuilders, and the end of the war found most traditional shipbuilders little further forward with the application of welding and assembly techniques.

At first, ambition levels with respect to steelwork assembly were limited to eliminating the need to joggle steel in order to facilitate the riveting of plates and shapes, whenever possible. This led to welded panels and then to welded stiffened panels. Internal structure was also welded into subassemblies which could be erected to form a skeleton; welded panels/stiffened panels were then attached to the skeleton like cladding. As time went on, the internal structure was added to the panels, and the size and weight of units became progressively larger.

The initial impact of the introduction of welding and assembly methods to shipbuilding included the following.

- o Effect of thermal distortion on dimensional accuracy.
- o Introduction of new production stages, for example, subassembly and unit assembly.
- o Breaking up of the previous continuity of responsibility from collection of material through to erection with its beneficial affect on quality and the "self-check" system of accuracy control.

During the early stages of this development process there was very little impact on outfitting work, since this was still done largely in the traditional manner, piece by piece after launch.

These early developments did not appear to impose urgent needs for changes in the organization of shipbuilding activities but, never the less, the need had already arrived. The major problem arose out of the effect of thermal distortion caused through burning and welding. The solution chosen by many shipbuilders was based on "green" or surplus material and overlapping joints. This limited the problem but resulted in a considerable amount of extra work.

The problem was further aggravated by the fact that introducing extra building stages and breaking up the squad system meant that the workers responsible for making the parts were no longer responsible for fitting them into units. Similarly, the workers responsible for assembling the units were no longer responsible for their erection at the ship. Thus, there was a clear need for the introduction of an accuracy control system which, we see now few shipbuilders successfully implemented.

This was standard until the late 1950's and early 1960's, when a series of events led to a completely new approach to shipbuilding production. There is little doubt that the primary motivating force was the rapidly increasing size of ships. This was supplemented by the desire to build larger units in order to reduce the work done at the erection stage, and by the fact that many older facilities needed modernization. The high cost of new slipways and building docks with large capacity cranes provided the primary requirement for dramatically reducing the number of such facilities, and Correspondingly, the length of the erection cycle time. These developments had an impact in six areas:

- o Flexibility Previously available through the long erection periods and the simultaneous construction of frequently four or more ships was lost. Other ways of providing necessary flexibility in the production areas had to be found.
- o Strict adherence to schedules became the "name of the game." This meant equally strict accuracy control and/or the use of processes which were not sensitive to variation in fit-up.

- o New management control data had to be established, since the change of shipbuilding method had invalidated virtually all the old data, including that used in the traditional payment-by-results systems.
- o The way in which manufacturing information was prepared, (that is, to suit the new production methods) had to be reorganized.
- o A new work breakdown structure was needed since ships were no longer built system by system.
- o A new basis for planning and monitoring production activities had to be established, not only because of the change of building method with its associated reduced production cycle times, but also because of restrictions on the building up and shedding of labor.

These needs are satisfied by the "modern method of ship construction" referred to later in this chapter.

1.2.1.3 The Development of Steelwork Assemblies - In the early days, steelwork assemblies were generally two-dimensional, with the exception of the fore and aft end blocks.

Initially, shell and deck plates were welded to form panels with riveted stiffeners. The next step was to weld the stiffeners to the plate panels. At this stage the majority of the hull was built using the following main assembly types:

- o flat stiffened panels
- o curved stiffened panels
- o corrugated plate panels
- o swaged plate panels
- o stiffened plate subassemblies

As ships became larger, the web frames and transverses became too unwieldy to handle in one piece and were therefore subdivided into a number of parts, each being assembled to its adjacent stiffened panel. Such assemblies were referred to as built-up stiffened panels. This progression is shown on page 1-2/109.

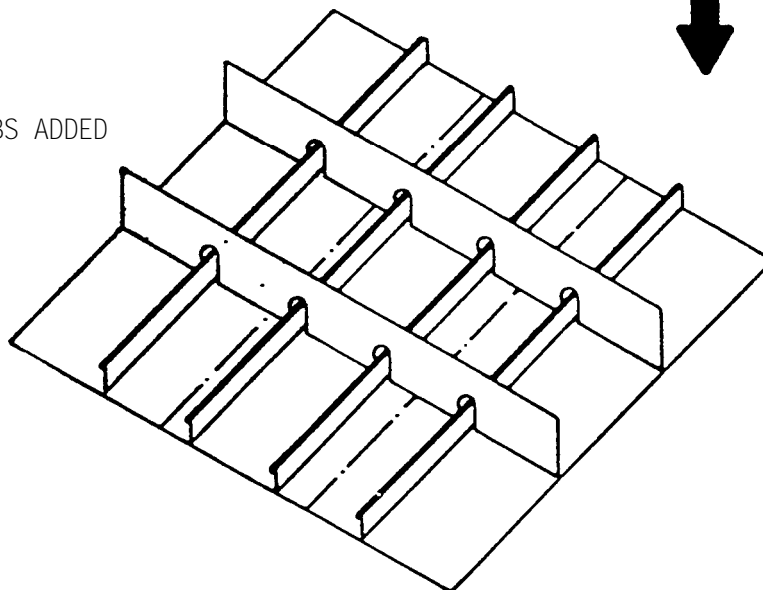
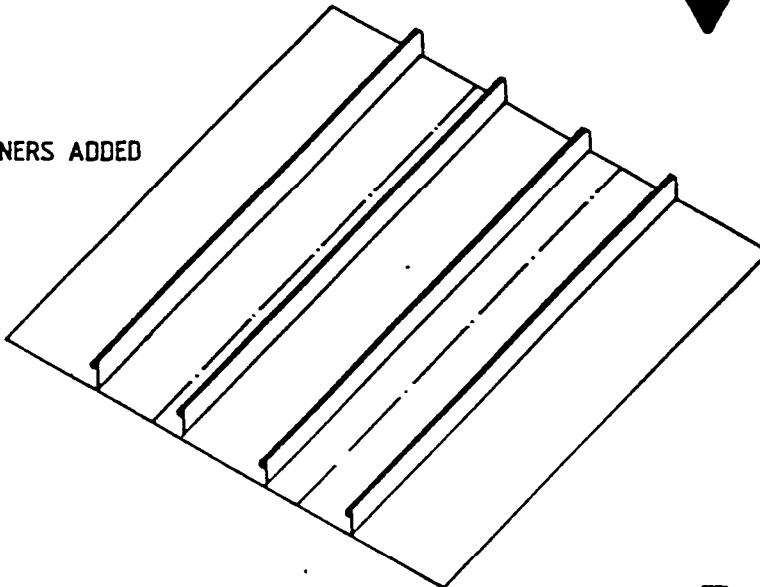
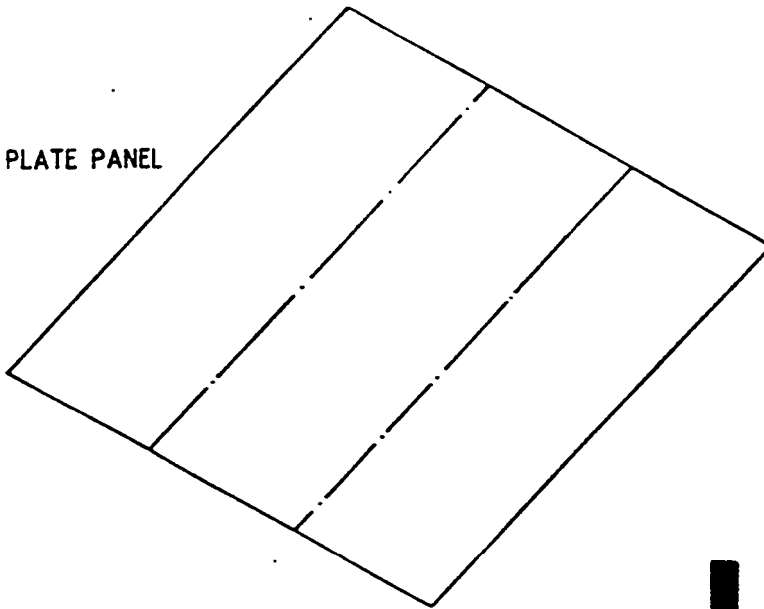
PLATE PANEL

1-2 /109

STIFFENERS ADDED

WEBS ADDED

ILLUSTRATION OF PROGRESSIVE USE OF ASSEMBLY METHODS



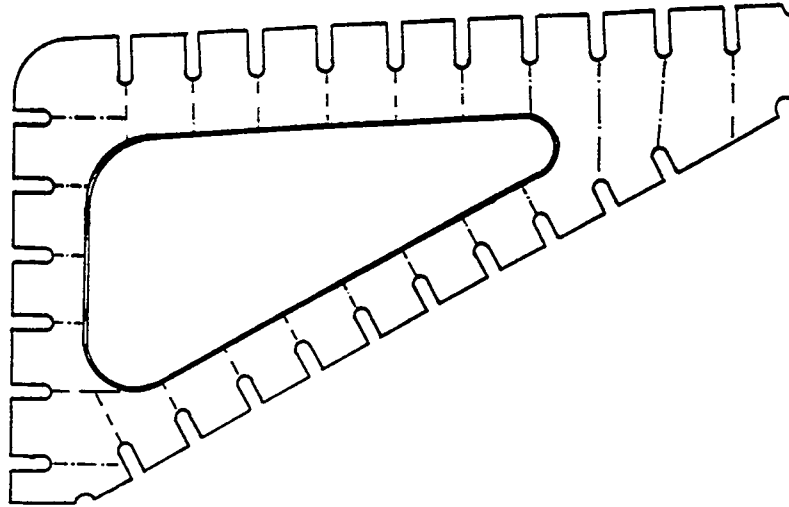
The figure on page 1-2/111 shows the way in which modern assembly methods have impacted on the design of web frames. Note the use of fillet welding wherever possible and the elimination of forming. Figure (i) shows a traditional web. Features worthy of note are:

- o It is a difficult shape to manipulate during assembly.
- o Cut as a single piece, it wastes plate material.
- o Made as a single assembly, it requires a long process time.
- o The curves face flat is difficult and time-consuming to fair.

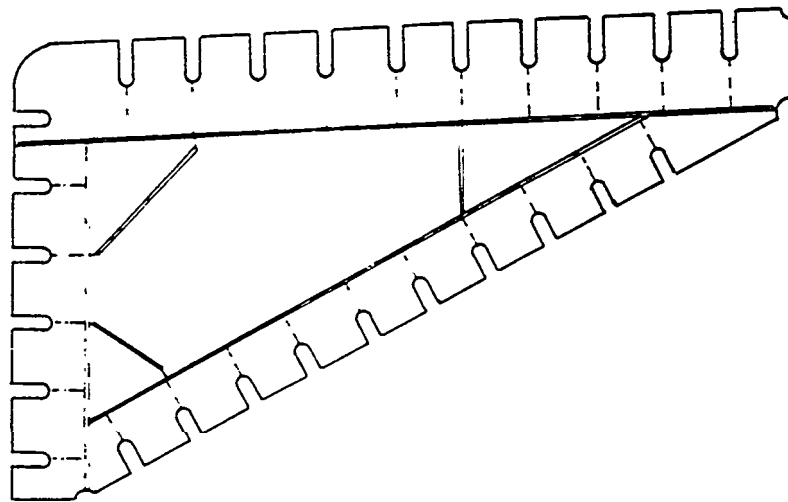
Figure (ii) shows an alternative design. There are more pieces and a small increase in weld length, but overall the design is more efficient:

- o Problems noted above for the traditional web are eliminated.
- o Fairing and welding of the face flats can be readily mechanized.
- o Production stages, using work stations, can be employed.

It should now be evident that although consideration should be given to the number of pieces in an assembly as well as to required weld length, these types of parameters should not be the only deciding factors. Production methods should definitely be considered, as we have seen on page 1-2/111.



(i) WEB DESIGN FOR EARLY FABRICATION
METHOD OF COBSTRUCTION

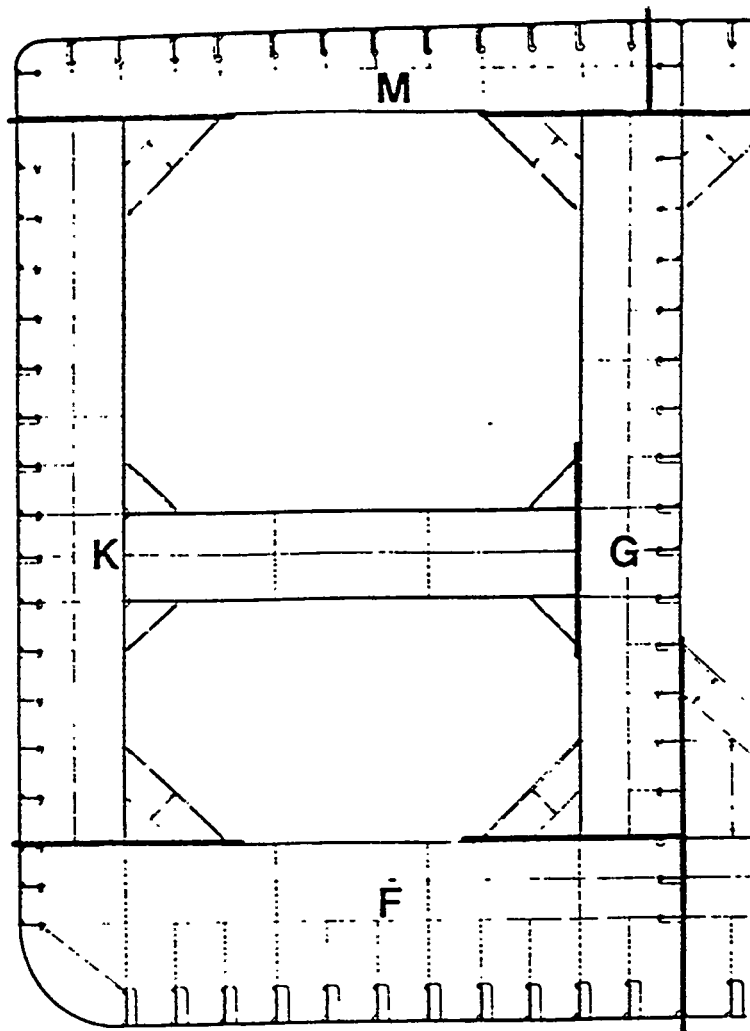


(ii) WEB FRAME DESIGN FOR BUILT UP STIFFENED
PANEL METHOD OF CONSTRUCTION

In the early days of ship assembly, the transverse parts G, K and M of the large tanker shown on page 1-2/113 were made into one assembly with the strut. A number of these transverse assemblies then were combined with the stiffened panels to form the wing tank of this particular vessel. Today, blocks G, K, and M are made as built up stiffened panels and then combined to form a three-dimensional block forming the upper part of the tank.

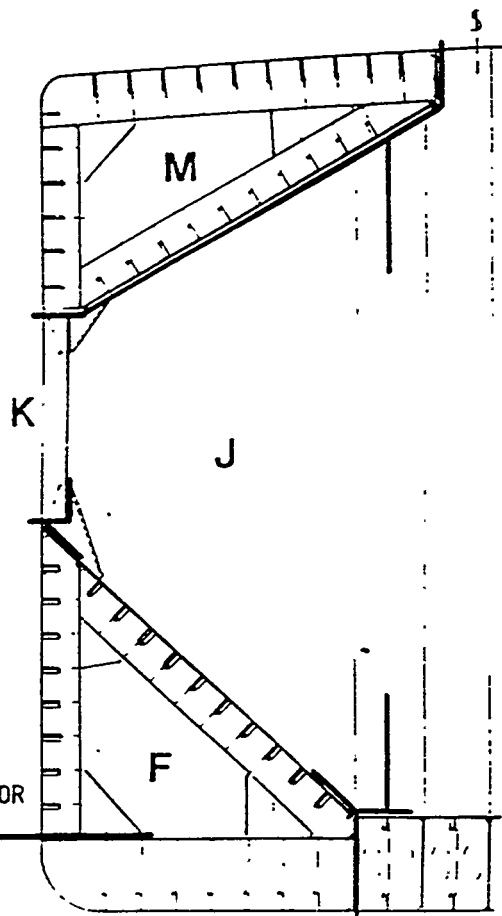
The figure on page 1-2/113 also illustrates how bulk carrier blocks F, J, K and M are combined to form a complete side unit of the vessel in more efficient modern shipyards. Shipyards employing such methods have significantly reduced erection work content and thus made large reductions in the cost of steelwork production. The larger steel blocks have also greatly facilitated the adoption of advanced outfitting methods.

As steelwork cycle times were reduced, it became necessary to increasingly overlap steelwork and outfitting activities. This ultimately meant that the same assembly technique had to be applied to outfitting together with the appropriate changes facilities, to work methods, and to the format of technical information, as well as to the planning of outfitting operations. This development was neglected by some shipbuilders, while others simply installed outfit items at an earlier stage on steelwork units but still largely piece by piece.



1-2 /113

SIDE TANK OF
LARGE TANKER



SIDE BLOCK OF
BULK CARRIER

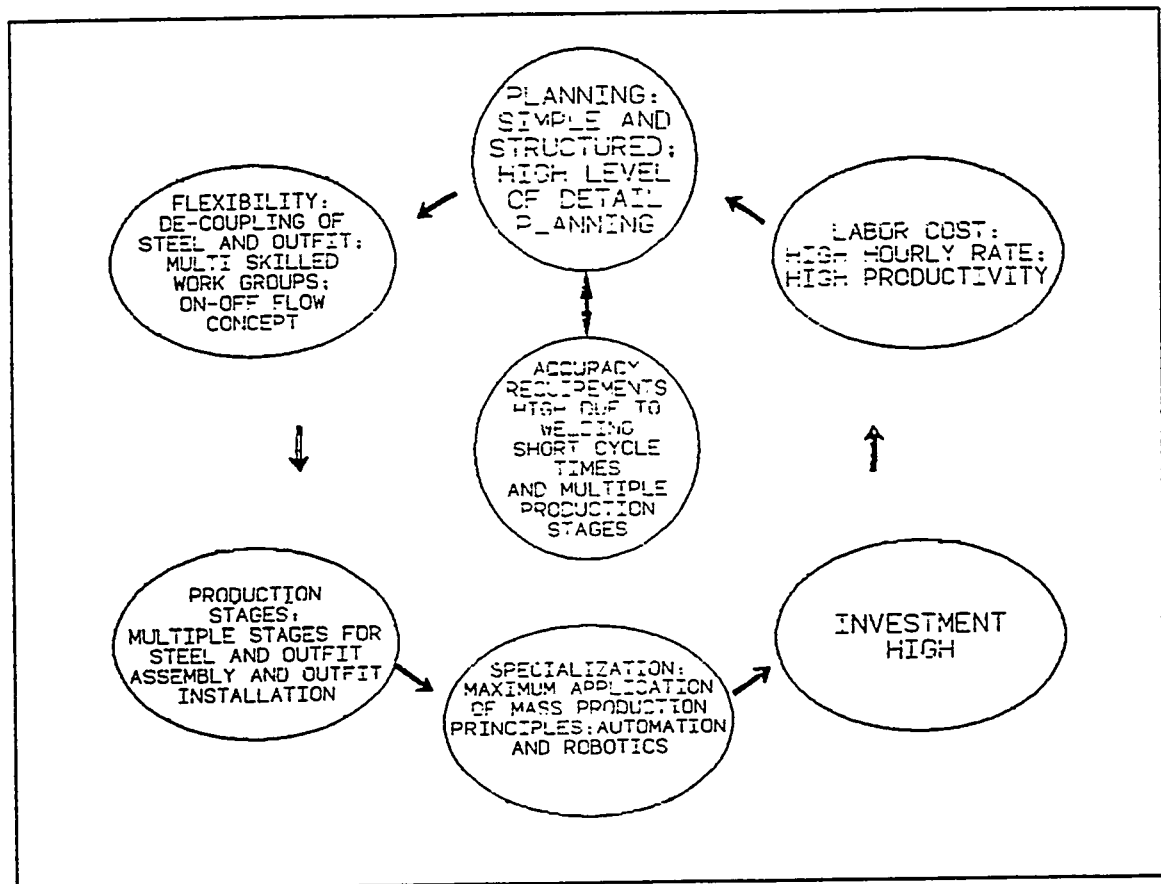
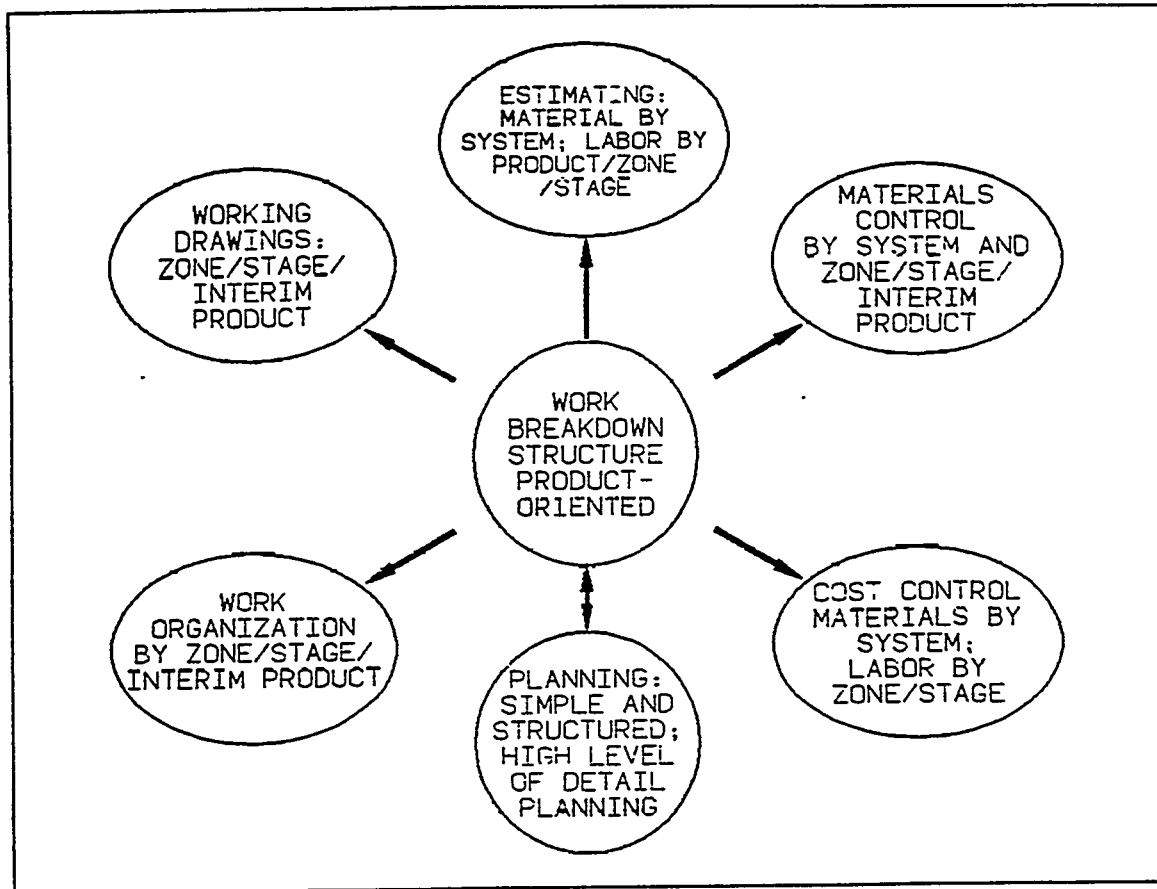
ALTERNATIVE POSITION FOR
SIDE BLOCK BREAK

1.2.1.4 The Modern Method of Ship Production - The most recent developments in shipbuilding technology have been motivated by the ever-increasing need for shipbuilders with higher-cost labor resources to reduce costs in order to remain competitive with shipbuilders enjoying lower-cost labor. This has led to significant improvements in product design. Furthermore, a specific objective has been to facilitate the eventual automation of a wide range of shipbuilding activities; and computers are used increasingly in this area.

These developments have brought significant benefits to many shipbuilders. They have not only enabled them to significantly reduce the overall production cycle time, but also to reduce the lead time between contract signing and the start-up of production. This allows the shipbuilder a considerable commercial advantage, especially at times of market uncertainty. It is also an advantage when new products appear on the market, since the shipbuilder can react more quickly to demand, and despite being second with the idea, can be first with the product.

Each company's shipbuilding policy, of course, will be unique. It will be shaped according to particular shipbuilding ambitions and objectives with regard to product range, rate of output, facility development, organization, build method, and so on. However, the policy must lead to a construction method and organization which exhibit the characteristics of the "modern method of ship production" shown on page 1-2/115. This is the way to improve productivity in a cost effective way, which will in turn potentially improve profitability.

- o The work breakdown structure is product oriented. The final product, the ship, is subdivided into a hierarchy of interim products which are progressively joined together, stage by stage, to make the finished product.
- o Work organization, working drawings, and materials control are correspondingly based on the same interim product hierarchy.



Modern method of ship production.

- o Estimating and cost control are product oriented for labor and system oriented for materials.
- o Planning is simple and structured. Control is by planning unit and department at the higher level and by work package and work station at the detail level. There is a high level of detail planning.
- o Flexibility is achieved by de-coupling of steel and outfit, by the use of multi skilled work groups and by the on-flow/ off-flow work concept.
- o There are a relatively large number of production stages and a high level of specialization at purpose-designed work stations.
- o There are relatively high investment, high hourly wage rates, and high productivity.
- o Accuracy requirements are high, with many changes in responsibility between stages. Control is exercised by the workers and foremen at each stage.

1.2.2 BASIS FOR SHIPBUILDING POLICY DEVELOPMENT

This chapter seeks to establish a framework for a new shipbuilding policy, setting out the basic objectives and concepts which, it is suggested, would form the basis for decision-making related to future organization, methods, and facilities development in a particular shipyard.

CROSS-REFERENCES

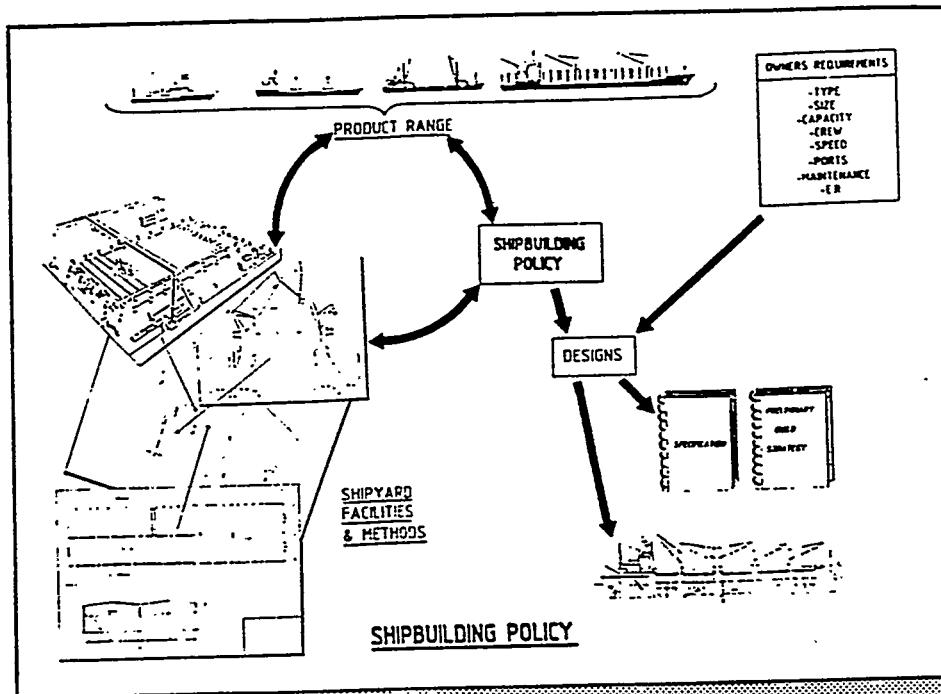
- 1.2.1 Impact of Welding and Assembly Methods
- 1.2.3 Implementation of Shipbuilding Policy
- 2.1.10 Implications of Short Lead Time
- 2.2 Ship Design Stages
- 2.4 Planning
- 3.2 Shipbuilding Policy

1.2.2.1 Basic Shipbuilding Objectives - Shipbuilding policy is the definition of the ideal or optimum organization and build method within the framework of the company's shipbuilding ambitions. Many companies need to develop new policies, either because they do not exhibit the characteristics of the "modern method of ship production" and of good work organization or because they are losing their competitive edge.

The shipbuilding objectives provide an important input to the development of a shipbuilding policy and must therefore be defined, at least in general terms. Basic objectives should usually include the following (see page 1-2/203).

- o To be Competitive in terms of project durations.
- o To maintain strict adherence to delivery dates.
- o To be capable of efficiently building "one of a kind" in a poor market situation.
- o To be competitive in terms of total cost.
- o To be profitable.

To shorten the project duration, it is necessary to reduce both preproduction and production cycle times. The reduction of preproduction time may be achieved through a policy of design rationalization and standardization so that drawings and specifications can be completed earlier.



BASIC OBJECTIVES

Competitive in total cost
 Competitive in project duration
 Maintain delivery dates
 Efficiently build "one-offs"
 Be profitable

Production cycle time may be reduced by simultaneously carrying out as many production activities as possible. This also means subdividing the vessel to minimize erection cycle time by reducing the number of erection blocks and providing erection faces, as many and as early as possible. This philosophy must then be applied to the blocks themselves and to subblocks and subassemblies. Outfitting must be approached in the same way with the maximization of outfit assembly work to reduce installation time. Modern shipbuilding is very much a matter of efficiently organizing the assembly processes.

It will clearly be advantageous to be capable of delivering vessels of a given type at a rate of at least, say, one every three months, in order to attract multiple orders. Thus the size and complexity of vessels built might be influenced more by the rate of output required (in terms of numbers of ships) from the shipyard than by the size of its building berths or docks. In practical terms, this means that although the berth or dock might be capable of accommodating a significantly larger vessel than normally constructed, there is little possibility of the shipyard building this class of vessel efficiently if the erection cranes are too small or if other key production activities are not matched to the required production rate.

Strict adherence to delivery dates in parallel with short production cycle times requires effective materials control and uniform levels of good dimensional accuracy. Without these ingredients, schedules cannot be drawn up with the necessary confidence levels. The development of consistent planning and control data requires a stable production system where similar tasks are undertaken by the same work groups, in the same work areas, using the same methods and equipment.

Many leading shipbuilders achieve high levels of productivity while building what appears to be a wide range of ship types and sizes. This has been accomplished through rigorous programs of design rationalization and standardization and by related organization of work in order to simulate the series effect. This, in turn, is achieved by the application of group technology and a product subdivision which leads to the formation of interim product families. The work content and sequence of operations of each member of a specific family are contrived to be approximately the same. These points are discussed in more detail in the following sections of this chapter.

1.2.2.2 Shipbuilding Policy Framework - The main elements to be considered in developing a shipbuilding policy are:

- o work breakdown structure
- o production and labor flexibility
- o production cycle time
- o pre-production cycle time
- o preparation of technical information
- o planning
- o accuracy control
- o coding and numbering systems

1.2.2.3 Work Breakdown Structure - Chapter 1.2.1 explained the importance of the work breakdown structure in terms of the organization of information, materials, and production workstations. The development of an appropriate work breakdown structure is therefore an essential part of the shipbuilding policy framework.

As noted earlier, the traditional method of shipbuilding involved the joining together and installation individual piece parts on a system basis. This process was essentially a sequential method of building in that there was little overlapping of steel and outfit work, and the erection and installation of piece parts in itself imposed a strict limitation on the scope for paralleling those operations.

The modern method of shipbuilding involves the joining together of assemblies. This approach enables parallel production methods to be used by dividing the ship into steel and outfit assemblies work can be more widely spread at an earlier stage of production, thereby enabling the overall production cycle time to be reduced. In addition to producing steel and outfit assemblies, the installation of outfit work may be done in parallel with steelwork, thus giving a further reduction in cycle time.

Clearly, the assembly method of production requires a different work breakdown structure to that used with the traditional method of shipbuilding, as it is area/assembly, rather than system/part, oriented.

Before selecting a revised work breakdown structure it is important to consider the impact of the assembly method on shipbuilding elsewhere. In the most competitive shipyards, the proportion of work done during the post erection period has been steadily reduced to the stage where up to 70% of the total man hours required to build a ship are expended doing pre-erection work in producing the parts and assemblies which, when combined, make up the end product, the ship. These parts and assemblies are referred to as the interim products. Thus it may be seen that modern shipbuilding production is essentially concerned with the making and combining of interim products and that the work breakdown structure should clearly be product oriented. Thus a product work breakdown structure is required.

Material flow in an assembly type production facility is designed to pass through a succession of production stages. At each-step or stage, parts and assemblies are joined together to make increasingly larger assemblies. The staging of production in this way is an important aspect of the assembly production method. It is not only the key to achieving a high degree of parallel production but is also the means of achieving a high utilization of each production area and of ensuring that each has the appropriate capacity and facilities.

An analysis of the way in which any assembly is put together will show that this work may be done in a series of steps according to its type and size. The work breakdown structure must therefore also provide a means of slotting interim products by production stage. The way in which this is done is first to subdivide the vessel into its erection blocks and post erection outfit installation work areas (zones) and then to further divide each into its various assemblies and installation packages through to piece parts. The resulting interim products are then analyzed according to their size and the processes and skills involved in their making, and hence slotted into family groups. Thus the product work breakdown structure will facilitate the progressive subdivision of the ship into its interim products by family and by stage of production.

1.2.2.4 Production and Labor Flexibility - During the past 30 years there has been a steady trend for shipyards to concentrate their ship erection on fewer berths. Consequently there are relatively few shipyards that build more than two medium or large ships at a time, and many build only one. Thus the flexibility afforded by the traditional multi-berth shipyard has had to be provided by other means. The more efficient shipbuilders have achieved high levels of flexibility through the design and subdivision of their ships. That is, by reducing the variety of the interim products, not only within ships but also from ship to ship.

This means that the work content within interim product types is contrived to be as nearly identical as possible. Where there is work of a significantly different nature to be done, this may be removed from the main body of the steel or outfit assembly, either as a subassembly or simply planned to be done at a different stage of production.

The proportion of the total steel weight of a ship that is contained within the cargo carrying part of the hull varies with its size. It is, however, the greater part and, for the larger cargo carrier, may constitute around 80% of the total steel weight. The structural arrangement throughout this portion of the hull is usually repetitive and it is therefore this area that most readily lends itself to being subdivided in a consistent manner.

If the objective is to make the lengths of the erection blocks as nearly equal as possible from ship to ship, it is necessary to subdivide the hull independently of the transverse bulkheads. However, in practical terms this means that side blocks should be self-supporting.

At the lower levels of manufacture, interim products produced on a main flow path would be contrived to be of similar size or shape, thus involving the same processes and work sequences. This approach is based on the application of group technology techniques. The primary objective will be to make as much of the ship as possible using the smallest possible number of process flow paths. The main flow paths are termed "on-flow." Work that cannot be done along main flow paths will be produced in special "off-flow" areas and will be reintroduced to the main flow paths at a later stage.

Those work stations doing on-flow work will therefore be capable of achieving very high performance levels since the work will be done using consistent methods, the same labor group, and the same tools and equipment. The fact that the work content of each interim product made in any given on-flow work station will be similar, will facilitate the achievement of a high level of effective working time in these areas. This is because the balanced workload will allow each team of workers to develop a work rhythm relative to the others.

A further requirement for achieving high levels of effective working time is to keep each work station uniformly loaded, and with the appropriate balance of work between work stations at every production stage. To achieve this, provide sufficient buffer time between stages to facilitate the smoothing of the inevitable fluctuations in the workload as they arise. Buffer time and storage levels must be managed carefully to avoid inefficiency and high inventory.

Buffer times, of course, imply buffer stock which will require buffer storage areas to be provided. The movement of buffer stock between work stations must be done at minimum cost since these operations do not contribute directly to the completion of the product. It is therefore crucial that efficient materials handling methods based on the batch load concept are installed along with the relevant equipment.

In today's shipbuilding environment, it is not possible to make large short term variations in labor resource as was the case with the traditional method of shipbuilding. Relatively small changes may be achieved through the use of overtime working area, in cases of a facilities bottleneck, shift working may be introduced. In the latter instance it is essential that there be a complete balance in labor skills between the shifts for any given work station, otherwise the work done by one shift will hinder that done by the other.

Another approach taken by a number of shipyards has been to try to provide workers with a wider range of skills so that more flexible working may be achieved. But by far the most successful approach to the problem of fluctuating labor (and facilities) resource requirements has been to utilize subcontractors, either *working in the* shipyard or on their own premises.

Many leading shipyards consider themselves to be assembly yards, and their primary objective to deliver as many ships as possible each year and to this end they will subcontract whatever and whenever necessary. Thus, it is suggested that an essential part of any proposed shipbuilding policy is the flexible and purposeful use of subcontractors, both internal and external. This is particularly necessary at times of high market activity or when there is a significant change in product type or mix. Off-flow and service type work is particularly suitable for subcontracting, as is any work that can be more economically produced outside the shipyard.

1.2.2.5 Production Cycle Time - The means of achieving the reduction of production cycle time may be very simply stated: implement the maximum amount of parallel production. In practical terms this means overlapping the steel and outfitting work and reducing the ship erection cycle time. The ship erection cycle time is determined by the number of transverse and longitudinal joints that need to be welded at the erection stage and by the level of dimensional accuracy achieved during assembly.

As the number of erection joints decreases, the size of the steel blocks increases along with their work content. It is therefore important to subdivide the blocks into assemblies and subassemblies so that these may also be produced in parallel, thereby reducing the time taken to finish - assemble each block as well as the time required from start subassembly to finish assembly. In this way the number of assembly workforces are increased, thereby allowing more work to be undertaken simultaneously while at the same time reducing the amount of work remaining at the block assembly and erection stages.

A parallel approach may be taken with outfitting work. The first step is to complete as much of this work as possible prior to launch, and as the erection cycle is reduced, it will be necessary to complete more of the outfitting work prior to erection. As the erection cycle time is further reduced it will be necessary to reduce the installation work content. This may be achieved by building outfit assemblies.

As the erection cycle is further reduced it might be necessary either to increase the time available for engine room outfitting by introducing semi-tandem erection methods or to significantly increase the size of engine room steel blocks thereby enabling a higher degree of completion of outfitting work prior to erection. In summary, then, the production cycle may be reduced by:

- o overlapping the steel and outfit work cycles,
- o reducing the steelwork content at erection, and
- o reducing the outfit installation work content after

In order to achieve short production times and to link the work done at each production stage it will be necessary to provide detailed technical information and to install effective planning and material control procedures. This is discussed later.

1.2.2.6 Pre-Production Cycle Time - Research into the nature of design work performed by a wide range of industries in Sweden in the early 1960's showed that only about 10% of design work is truly innovative. The remaining work may be classified as the selection and use of standards of various kinds and the combination and modification of standards to meet a new specification or requirement.

The conclusion of this research was that the most significant improvement that could be made to the design process was the implementation of a means of improving the retrieval of standard design information to enable the designer to perform more effectively the selection, combination, and modification of standard data (which constitutes 90% of design work). Many shipbuilders are now following this approach.

The first step taken toward improving retrieval was to rationalize existing designs and hence develop a range of "standard" arrangements, each of which offered a limited range of detail variations. Material lists were then prepared for each of these "standard" arrangements and these were stored together with details of equipment mounting data, etc., so as to provide a rapid means of data retrieval. The final stage was to establish a computer database for this information and to link it to a CAD/CAM system and to the main planning and material ordering systems. Significant reductions have been made in the overall design period as a result of these developments, but also quite dramatic improvements have been made with regard to material ordering. Up to 80% of material requirements may be ordered with only 30% of the design work completed.

The commercial advantages of achieving these figures are clear and no shipbuilder can afford to ignore them. Furthermore, the advantages to be gained in production from the standardization of arrangements should not be underestimated.

1.2.2.7 Preparation of Technical Information - Chapter 1.2.1 drew attention to the relationship between technical information and production method. It was shown that the system method of ship construction was compatible with the preparation of technical information by system. Furthermore, since the only stages were pre- and post-erection and installation, design information was produced accordingly, with information for the making of parts being prepared by the workers through the loft (steel) and sketchers (outfit).

Clearly, the assembly method of shipbuilding requires a different approach in terms of the way in which technical information is prepared. Technical information should be structured to meet two basic requirements:

- o to complement the way in which the product is subdivided (that is, according to the product work breakdown structure). and
- o to provide each area of responsibility (that is, work station) with information covering only that for which it is responsible.

In practical terms this requires that technical information be structured according to zone-by-stage-by-interim product.

An essential aspect of the technical information/production interface is the identification of interim products and the material or parts from which these are made. With the traditional method of shipbuilding there were few basic rules. These may be summarized as follows.

Steel work:

- o Each part was identified with the material from which it was to be made.
- o Each part was identified with the system to which it belonged and its geographical location within the ship.

Outfitting:

- o Each part was identified with the system to which it belonged and with its specific location within that system.
- o Equipment and fittings were identified with their system and position.

All parts, material and equipment were, of course, identified with their respective ships. The basic rules still hold, but they must be adjusted to suit the new production method, especially regarding the various production stages. At each new stage the material, part, or assembly takes on a new identity. The development and use of a material, part, and assembly identification system is therefore essential in the development of a shipbuilding policy. The rules for the new identification system are somewhat more involved (and numerous) than for the old:

Steel work:

- o The ship is subdivided into blocks which identified by means of their geographical location within the ship.
- o Shipyard standard parts and subassemblies which are produced in numbers exceeding approximately 25 are identified by their ship standard number, which also is keyed to the block type to which each part belongs.

N. B. Standard parts are usually made from standard material.

- o Other material, parts, subassemblies, and assemblies are uniquely identified with the steel block to which they belong and also with respect to the work station at which the work is to be done.

Outfitting:

- o Outfitting work is divided into two categories: pre- and post-erection.
- o The hull, engine room and accommodation areas of the ship are subdivided into zones.
- o Outfit assemblies are identified and classified as pre- or post-erection type.
- o Pre-erection outfit parts and assemblies are identified with the steel block into which they are to be installed. They are also identified by the work station where they are to be manufactured or assembled.
- o The stage at which outfit parts and assemblies are installed in steel blocks will be identified.
- o Post-erection outfit parts and assemblies are identified with the zone into which they are to be installed and with the installation stage. They also are identified by the work station where they are to be manufactured or assembled.
- o Outfit standard parts are identified with their standards number.
- o Outfit equipment and fittings standards are identified through their standards number.
- o Other outfit equipment and fittings are classified as pre- or post-erection and are identified respectively with the block or zone into which they are installed and with the installation stage.

Initial orders may be placed for materials and equipment by system rather than by block or zone. In such cases materials and equipment lists will be drawn up by block and zone at the earliest possible time as more detailed design and planning information becomes available.

In order to simplify planning and production operations it is important that steel materials be ordered and nested by block or pair of blocks and by production stage. The only exception to this rule will be standard parts which would normally be made from standard material sizes.

1.2.2.8 Planning - The planning of large "one of a kind" type projects is usually very complex, due principally to "in house" lack of knowledge and related experience data regarding the work to be done. Thus if large sections of any given project can be identified as being identical or even very similar to work done on earlier projects, these can be planned and scheduled with a higher degree of reliability.

These shipyards which have developed a consistent approach to the building of ships have extended this concept to basic design. Such shipyards claim that simple production means simple planning. By this they imply that only those aspects of the design which are significantly different from anything that has been done before need in-depth analysis. The remainder will, as a matter of normal practice, be designed, subdivided, manufactured, assembled, erected, and installed in the same manner as previous projects. Work is planned for the same work stations manned by workers having the same training and skills and employing the same methods.

The fundamental objective with this approach is to develop a "game plan" which, once established, is maintained by aggressively adhering to target dates.

Experience has shown that this frequently requires a degree of retraining to change attitudes and how management control systems are set up:

- 0 The total workload should be divided into clearly definable control "packages" to be completed in a time span which is short relative to the overall time span of the project. These are defined as planning units.
- 0 The work left to be done (or alternatively, the state of completion) should be quantified in specific terms. An estimate of percentage completion is not a satisfactory basis on which to determine reliable completion dates.
- 0 If a job is held up due to design change, lack of approval, faulty workmanship, it must be analyzed to identify those parts of the job that may proceed according to the original plan. Those areas directly affected by the delay must then be replanned and completed independently.
- 0 Problems related to the completion of a job at any work site must not be allowed to cause a chain reaction effect on future work scheduled for that work site.

It is important to note that it is highly unlikely that the cost of any remedial action required to maintain program dates will be significant when compared with the loss of income resulting from a delay of even one day in the programmed delivery date.

It is also important that everyone in production management understands the problems and chaos that can result from not adhering to an agreed work sequence. This applies not only to the erection or installation sequence but also to the sequence of assembly, manufacture, and preparation of drawings. This is because at any one time there are thousands of interrelated activities under way from design, to material delivery, to final commissioning and testing. Thus recovery of a slippage in the program is much more likely to be achieved by squeezing the remaining timescale than by altering the basic sequence.

With traditional shipbuilding method where the ship was constructed by system, there was a consistent method of determining the completion of the work to be done throughout systems testing and commissioning program. With modern assembly method, completion of work is monitored by planning unit.

There are basically two types of planning unit: pre- and post- erection. Pre-erection planning units are single blocks or pairs of blocks (steel) and outfit assemblies (outfit). Post-erection planning units are zones which may be physical areas, or alternatively, activities such as installing and chocking the main engine, boring out, and shaft alignment.

For effective control of the work done in each planning unit, it is important to include an inspection activity to be performed on the scheduled completion of each. At this inspection, incomplete work would be listed in specific terms: just as the work to be done in the first instance must be similarly listed. In this way the list of unfinished work becomes, or must be added to, the specific list of work to be done at the next stage. Thus, the seven basic requirements are:

- o There must be a high level of standardization in design. This does not imply that there must be only one of anything but rather that there should be a limited number of variations.
- o There must be a formal standard approach to the sub-division of the product.

- o There must be a formal standard method and sequence of making the product.
- o There must be a consistent approach to the manufacture and assembly of interim products.
- o Maintaining the "game plan" and adhering to schedule dates must be basic objectives and attitudes throughout. The organization must be aligned with these objectives.
- o There must be consistent control of planning units which reflect the assembly method of production.
- o Work to be done at any stage of production must be quantified in specific term through the use of working drawings, parts and material lists and work instructions which are structured according to the way in which production is organized.

Once the above requirements have been met, planning is essentially, a matter of organizing for the relevant material and technical information to arrive at each work station at the appropriate time.

1.2.2.9 Accuracy Control - It may be said that the level of dimensional accuracy achieved by any shipyard ultimately determines its level of productivity. Establishing an effective accuracy-control system is therefore an essential part of any shipbuilding policy development program.

Dimensional accuracy is especially important in the following areas:

Planning: Variations in dimensional accuracy frequently lead to disproportionately large variations in work content and hence in the time taken to complete the work. This means that it is difficult to predict completion dates and this runs contrary to one of the basic planning objectives.

Erection and Installation: Short erection cycle times cannot be achieved without an effective system of accuracy control. It is therefore important to ensure that the vast majority, if not all, steel blocks are made such that they will not require trimming to size after erection. This is important also in terms of outfit installation work.

Rework: The practice of leaving on extra material rework which, if done excessively or without a formalized approach to its removal, can significantly add to production costs. determined, through the use of statistical methods, normal accuracy welding processes and methods. These data have then been used to determine methods of reducing and correcting angular and linear the adding on of excess material to allow for predetermined distortion such that dimensions, on completion of manufacturing or assembly operations, fall within Prescribed tolerance bands.

Curved Shell: Plate material that has been formed to take on single or double curvature becomes very stiff. Strict control must therefore be established over the dimensional accuracy of such parts, with each subjected to a stringent check procedure before being allowed to leave the preparation workstation. These tests relate not only to the form at each frame station but also to the angle of twist and set along the plate.

Production Stages: The assembly method of production with its multiple stages means that responsibility for maintaining dimensional accuracy changes several times between the part manufacturing and block erection stage. It is therefore necessary to train production workers to apply strict self check procedures at each stage of production to ensure that faults are corrected at source. These self checks are monitored by the foremen find by the dimensional control inspectors.

The effective application of control techniques implies the extensive use of statistical data. If meaningful data are to be collected and analyzed, then relatively standard work procedures and methods must be instituted, and standard skills ensured. This approach supports the organization and planning of work according to the interim product by stage concept.

Another important aspect of accuracy control is the introduction of a standard way of dimensioning parts and assemblies and of establishing a set of datum lines to facilitate both the measurement of distortion and the assembly, erection and installation of interim products.

1.2.2.10 Coding/Numbering Systems - The way in which numbering systems are structured either greatly assists or severely impedes the control and organization of work. This depends on whether or not they reflect how production is carried out. The development of numbering systems has been hindered because ship production methods have evolved slowly and because users of numbering systems have always been reluctant to lose the basis on which their "experience data" had been built up.

Numbering systems are considered in some detail in Chapter 3.3.8. However, it is important at this point to make some basic recommendations regarding their development. Numbering systems are required for:

- o item identification
- o planning and work ordering
- o cost control
- o drawing identification

Experience has shown that systems based on a combination of letters and numbers are generally more acceptable to production personnel. They are more readily understood and remembered and therefore are less liable to lead to mistakes.

"Item identification" rather than "part numbering" has been deliberately used since identification in the fullest sense is the primary function of the numbering system.

When developing hull steel and outfit numbering systems, it is essential that identification include not only what the item is, but what it belongs and into which planning unit it is to be ultimately installed. Outfit items that are installed into blocks prior to erection would be identified with the pre-erection planning unit (the block) and not the post-erection planning unit (the zone).

Items which are to be produced repetitively may be withdrawn from the normal item identification structure and identified as ship standard or stock items. These items would be appended to the planning unit or interim product by stage item lists, in the same way as nuts, bolts, and washers would be added to any industrial assembly parts list as and when necessary.

Simplified control of material is the key to achieving simple production, and appropriately structured numbering system is an important contributor to this objective. Changes taking place at this time in the shipbuilding industry worldwide are based on Group Technology. Interim products are manufactured, fabricated, or installed at specific work stations, and the numbering or coding system must support this activity.

1.2.2.11 Summary - The eight basic aims in developing a shipbuilding policy are:

- o To reduce overall costs.
- o To reduce production lead times.
- o To reduce production cycle times.
- o To establish a consistent approach to shipbuilding, based on the assembly method of production.
- o To define the maximum amount of work at the detail design stage.

- o To control production through the effective control of material and technical information,
- o To ensure that, while there is a rigid approach to maintaining schedule dates, there is adequate flexibility within the overall-strategy to achieve this objective.
- o To change attitudes through appropriate training methods so that everyone understands the necessity for change and the importance of team discipline.

Previous sections of this chapter have attempted to identify the basic components which when assembled together provide a framework for the development of a shipbuilding policy. It is still necessary to develop the policy in detail but if the ground rules listed are applied rigorously to decisions regarding how, where, when, and with what the various shipbuilding operations should be carried out, the end result is likely to be much better than if these decisions are based on opinion and past experience which may no longer be relevant, or on local rather than overall system considerations.

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1.2.3 IMPLEMENTATION OF SHIPBUILDING POLICY

This chapter takes the objectives defined for shipbuilding in Chapter 1.2.2, sets them in the context of a business policy, and describes how they can be met. It is proposed that the company shipbuilding policy should generally be implemented at three levels:

- o Strategic
- o Tactical
- o Detail

The content of the policy at each level is briefly reviewed, and the link with the design function is established.

Cross-References

- | | |
|-------|--|
| 1.2.2 | Basis for Shipbuilding Policy Development |
| 1.2.4 | Contract Build Strategy |
| 2.1.6 | Impact of Facilities on Design |
| 2.1.7 | Need to Document Facility Capability |
| 2.1.8 | Need to Document Production Process and Method Information |
| 2.2 | Ship Design Stages |
| 2.4 | Planning |
| 3.1.2 | Production Engineering Decisions |
| 3.3 | Shipbuilding Policy |

1.2.3.1 Overall Policy - A shipbuilding company will have an overall set of business objectives which have been established by the highest level of the company. Meeting these objectives will require a set of policies covering the whole range of company activities, including, for example:

- o marketing
- o product development
- o personnel
- o shipbuilding
- o accounting

It is with shipbuilding policy that this chapter is concerned.

Shipbuilding policy is the response of the planning, technical, and production part of the company to the overall business objectives. It therefore forms, along with similar responses from other departments or divisions, part of the overall policy of the business. The overall policy will include strategy on such key subjects as:

- o product range
- o shipyard output and capacity
- o cost targets
- o pricing policy

These set a series of targets for the technical and production part of the organization. To meet these targets, a set of decisions are required on:

- o facilities development
- o productivity targets
- o make, buy, or subcontract
- o planning, technical, and production organization

These form the core of the shipbuilding policy. The next level in the hierarchy defines the set of strategies by which this policy is realized.



Shipbuilding Policy is Part of Overall Company Policy

It Defines How the Technical and Manufacturing Function Will Meet the Requirements Imposed

The development of a shipbuilding policy is one of the central themes of this manual. The title Design for Production presupposes that the production data exists in a form which the designer can utilize. Although the primary function of the shipbuilding policy is to define, for internal use within the shipbuilding company, how business objectives can be met, it also has a very important role in design/production integration.

Many aspects of design for production can be incorporated in a vessel independently of specific production methods and processes, and in this way the work content of a design can be reduced. However, if the particular capabilities and constraints are not taken into account, details which the designer believes aid producibility might actually have no effect. Those aspects which can be developed independently will generally only be at the level of structural or outfit detail.

To meet tight launch dates, the number of blocks to be erected might well be critical. This can only be influenced during the design process if the relevant production data relating in particular to maximum plate size and block weight are available. The productivity gains to be made from better producibility at this level might exceed those at the detail level. In addition, the impact of reduced (or even achieved) delivery times on cash flow and overhead is considerable.

The various elements of a clearly defined shipbuilding policy form a significant input into the design process at various stages from conceptual to detail. The development of such a policy is therefore essential both for definitive and procedural purposes.

In summary, shipbuilding policy, as part of the overall company policy, defines how the technical and manufacturing functions will meet the imposed requirements.

Shipbuilding Policy: Context

- o market analysis
- o product development
- o financial objectives
- o personnel objectives
- o overall company objectives

1.2.3.2 Elements of Shipbuilding Policy - In essence, shipbuilding policy comprises a set of standards which can be applied to contracts. The standards apply at different levels:

- o Strategic: related to type plans, planning units, interim product types, overall facility dimensions, and so on, applied at the Conceptual and Contract Design stages.
- o Tactical: related to analysis of planning units, process analysis, standard products and practices, and so on, applied at the Functional and Transition Design stages.
- o Detail: related to work station operations, and accuracy tolerances, and applied at the Detail Design stage.

The levels of shipbuilding policy correspond in broad terms to the various design stages and to the levels of planning in the organization. The policy follows the same hierarchical pattern:

Level s/Stages		
Design	<u>Shi pbui l di ng Pol i cy</u>	Pl anni ng
Conceptual	Strategi c	Strategi c
Contract	Strategi c	Strategi c
Functional	Tacti cal	Tacti cal
Transi ti on	Tacti cal	Tacti cal
Detai l	Detail	Detail

Because shipbuilding is dynamic in that there is a constant program of product development and process development, the standards to be applied will change over time.

The shipbuilding policy is therefore consistent, in the short term, but will undergo a structured process of change over a period of years in response to product development, new markets, facilities development, and other variations.

The policy has a hierarchy of levels which allow it to be applied in full at any time to a particular contract. However, the policy which would be applied in a year's time would not necessarily be the same. Improvements in methods might be incorporated as the result of experience or of a facilities development plan.

To link the current policy with a future policy it is proposed therefore that there should be a series of projects for change, which are incorporated into an overall action plan to improve productivity. Since facilities are a major element in the policy, a long-term development plan will exist which looks to a future policy in that area. This will be developed against the background of future business objectives, expressed as a plan covering a number of years. (See page 1-2/307).

Elements of Shipbuilding Policy

Policy Overview

- o policy based on business plan objectives
- o sets objectives for lower levels

Current Practice

- o existing standards
- o "last best" practice
- o procedures to be applied to next contract

Productivity Action Plan

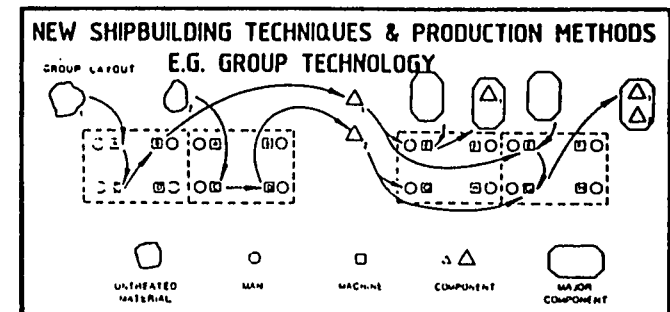
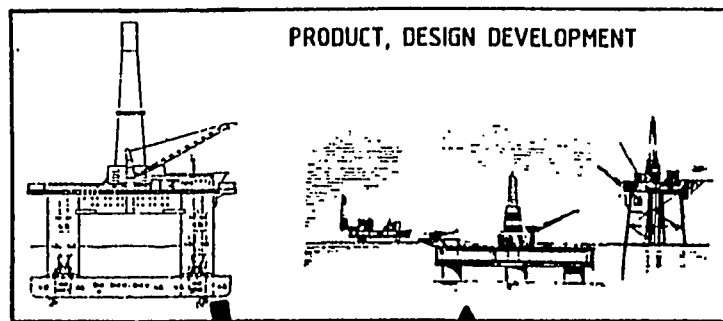
- o covers next twelve months
- o plans improvements in specific areas
- o is a set of projects

Future Practice

- o developed from current practice
- o incorporates outcome of action plan
- o procedures to be applied to future contracts

Long Term Development Plan

- o covers facilities development
- o covers a five-year period

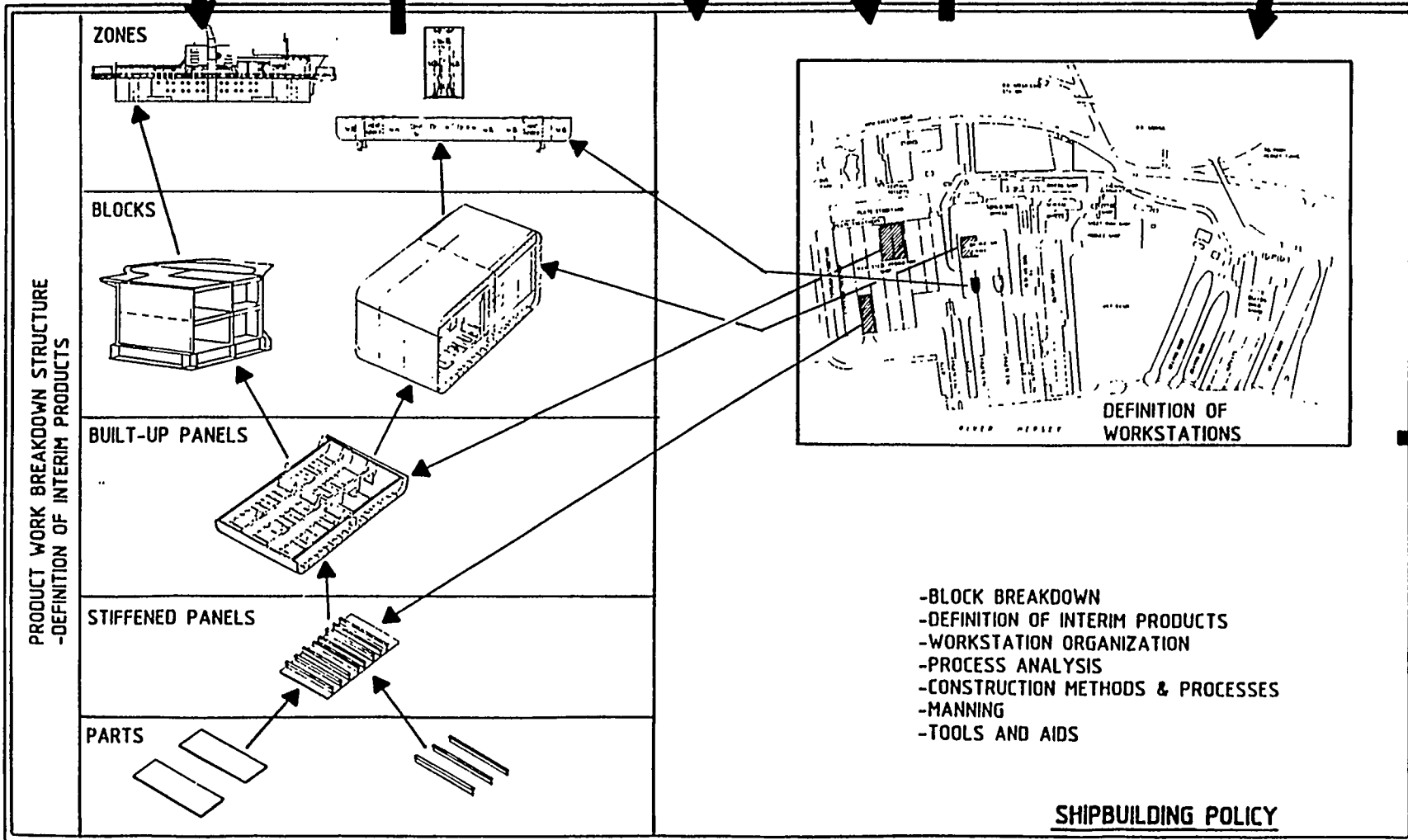


CORPORATE OBJECTIVES

SHIPYARD FACILITIES

EXISTING FACILITIES

FACILITIES DEVELOPMENT



BUILD STRATEGY DOCUMENT
(FOR EACH CONTRACT)

1.2.3.3 Strategic - Work at this level provides inputs to (see page 1-2/311):

- o conceptual and contract design stages
- o contract build strategy
- o facilities development
- o organizational changes
- o tactical level of shipbuilding policy

At the strategic level, a set of documents would be prepared which address the preferred product range. For each vessel/type, the documents will include:

- o definition of main planning units
- o development of type plans showing sequence of erection
- o analysis of main interim product types

The strategic level will also address the question of facility capability and capacity.

Documentation on the above will provide input to the conceptual design stage except, of course, in those cases in which a design agent is undertaking the design work and the builder has not been identified.

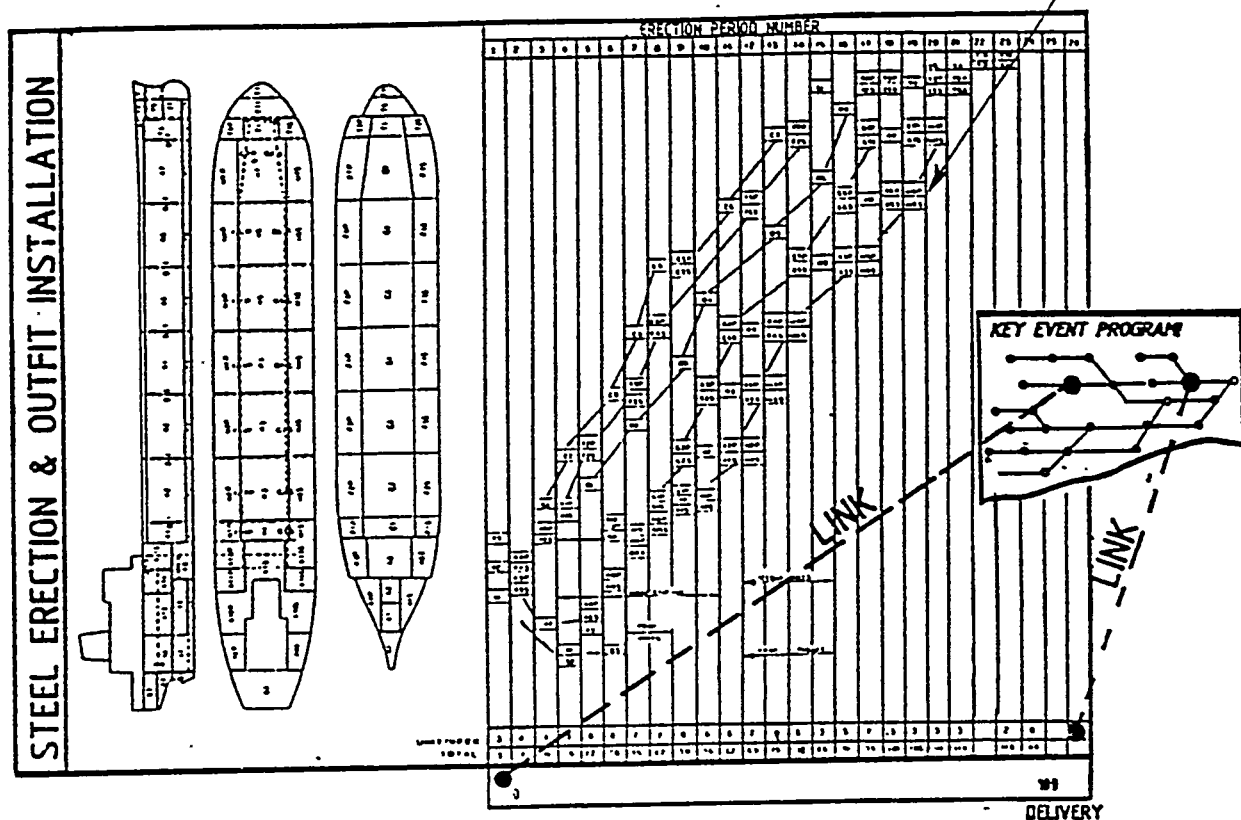
Documentation providing input to the contract design stage will include:

- o Preferred raw material dimensions.
- o Maximum steel assembly dimensions.
- o Maximum steel assembly weights.
- o Material forming capability, in terms of preferred hull configurations.
- o Standard preferred service routes.

PLANNING UN

-BLOCKS
 -PAIRS OF BLOCKS
 -OUTFIT ASSEMBLY
 -ZONES

TYPE PLAN



- DEFINES HOW VESSEL WILL BE BUILT
- IDENTIFIES MAIN PLANNING UNITS
- BASIS OF BUILD STRATEGY ERECTION PLAN
- IS CONSISTENT BETWEEN VESSELS

1.2.3.4 Tactical - At the tactical level, standard interim products and production practices related to the contract and transition design stages and to the tactical planning level will be documented (see page 1-2/313).

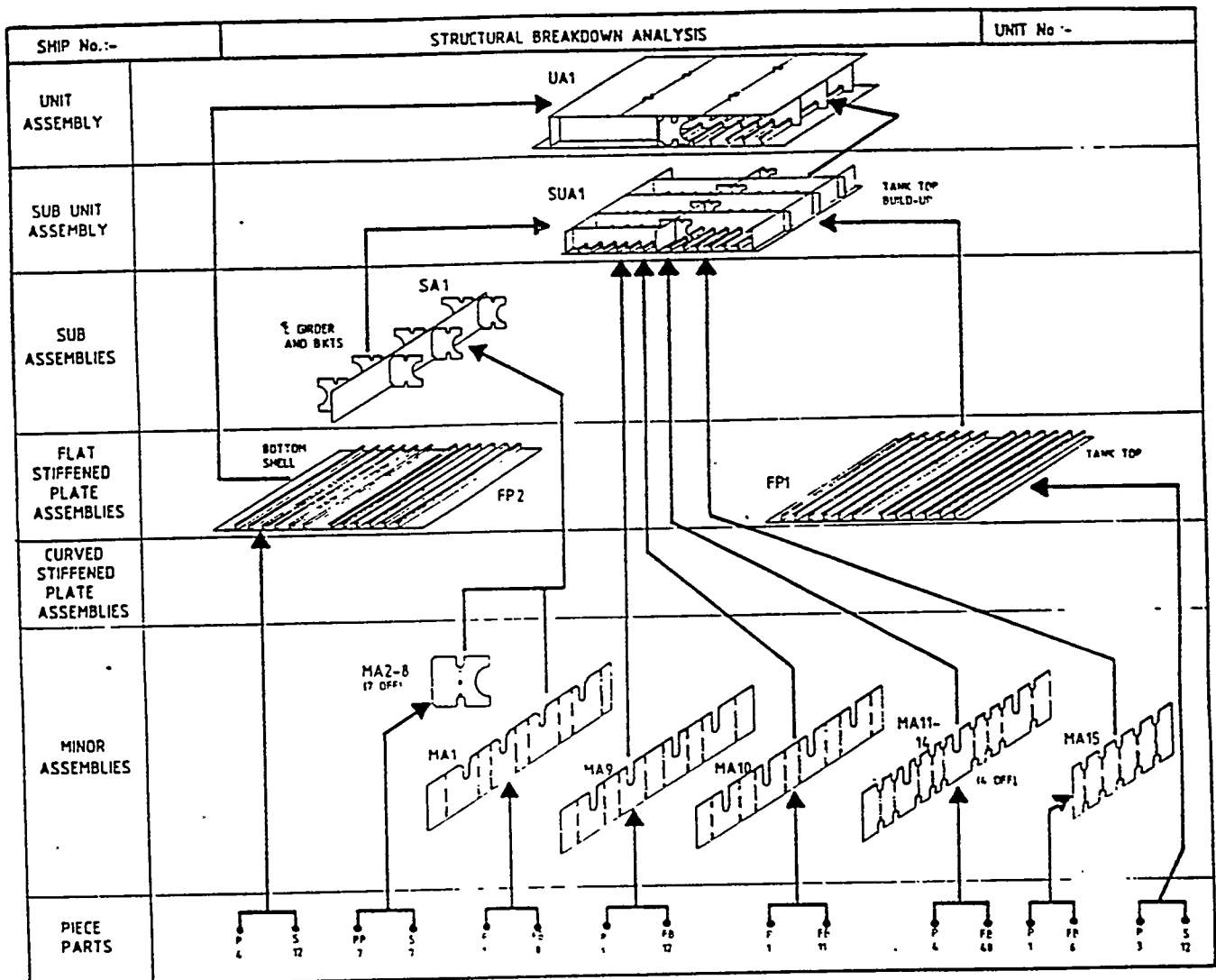
Also, at this level, all planning units will be analyzed and broken down into a hierarchy of products. The policy documents will define preferences with respect to:

- o standard interim products
- o standard production processes and methods
- o standard production stages
- o installation practices
- o standard material sizes
- o standard piece parts

The capacity and capability of the major shipyard facilities will also be documented.

For the planning units, subnetworks will be developed which define standard times for all operations from installation back to preparation of production information. These provide input to the planning function.

PROCESS ANALYSIS



- MAIN PRODUCT TYPES
- OUTLINE DESCRIPTION
- STANDARD PROCEDURES

ADDED TO EACH CONTRACT

1.2.3.5 Detail - At this level, the policy provides standards for production operations and for detail design (see page 1-2/315). The documentation will include:

- o work station descriptions
- o workstation capacity
- o workstation capability
- o design standards
- o accuracy control tolerances
- o welding standards
- o testing requirements

Reference to the standards should be made in contracts, and relevant information made available to the design, planning and production functions. As with all levels of the shipbuilding policy, the standards are updated over time, in line with product development and technological change.

SHIPYARD NAME		MAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION		REV DATE		
WORKSTATION DEFINITION				
NAME	Plate Joining			
LOCATION	SHEET 1 OF 5			
DESCRIPTION				
DISPATCHED TO				
DISPATCHED FROM				

1-2 /315

SHIPYARD NAME		MAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION		REV DATE		
WORKSTATION CAPABILITY				
NAME	Plate Joining			
LOCATION	SHEET 1 OF 5			
DESCRIPTION				
DISPATCHED TO				
DISPATCHED FROM				

SHIPYARD NAME		MAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION		REV DATE		
WORKSTATION DEFINITION				
NAME	Plate Joining			
OUTLINE DRAWINGS	SHEET 4 OF 5			
SCALE				

WORKSTATION DESCRIPTION

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1.2.4 CONTRACT BUILD STRATEGY

Each new or potential ship contract received by the shipyard requires the formulation of a build strategy. The build strategy is the application of the shipbuilding policy to a particular contract, and may be drawn up formally or informally. Where a shipyard has been working to a relatively uniform construction method over a period of years, much of the work to be done in completing the build strategy would be produced quickly with most attention being given to those areas identified as being unusual.

In the climate of change now being experienced, a structured and documented approach is recommended. The contract build strategy should normally be produced in the form of a single document; the development of that document is the focus of this chapter.

CROSS-REFERENCES

- 1.2.4 Implementation of Shipbuilding Policy
- 2.2 Ship Design Stages
- 2.4 Planning
- 3.1.2 Production Engineering Decisions
- 3.1.7 Process and Spatial Analysis
- 3.3 Shipbuilding Policy

1.2.4.1 Introduction - A well organized shipbuilder will have a set of facilities which are designed to suit a chosen product range. The production methods in use will meet the requirements of that product range, and will be supported by various technical and administrative functions. Such a coherent set of facilities and systems will be documented to provide a well-defined Shipbuilding Policy.

When a new order is taken, the policy can be applied, and only those parts of the design which differ from the standard design will require detailed investigation. In reality, as products change over a period of years, and as production facilities and methods are developed, a considerable drift can occur. As a result the vessel designs may not be updated to match new facilities and the production methods may not be optimized for new design requirements. A formal method is therefore needed which will enable changing requirements to be identified and absorbed systematically.

Thus it is essential that each new vessel undergo a systematic scrutiny to determine the proposed construction method, to list key events and their timing with respect to the overall project duration, and to identify possible problem areas and bottlenecks so that these can be resolved before production begins.

The output from the evaluation of the vessel and the definition of the means of producing it is the contract build strategy. Part of the strategy may include the modification of facilities, or changes in work practices.

Shipbuilding Policy Defines Primary Objectives - What The Company Is Working Towards.

Contract Build Strategy

- o Applies Overall Policy To A Contract
- o Ensures All Departments Contribute
- o Identifies Problems In Advance
- o Finds Solutions To Problems
- o Ensures Communication And Consistency

Contract Build Strategy Is An Agreed Building Plan Before Work Starts.

1.2.4.2 Objectives - The contract build strategy has ten specific objectives.

- o To ensure that the company shipbuilding policy is applied in contracts, and that standard methods are used as far as possible.
- o To ensure that all relevant functions and departments are able to contribute to the planned construction of the vessel.
- o To provide a process for ensuring that design development takes full account of production requirements.
- o To introduce systematically production engineering principles that reduce vessel cost, work content, and cycle time.
- o To identify interim products and to create a product-oriented approach to engineering and planning of the vessel.
- o To determine resource and skill requirements and overall facility loading.
- o To identify shortfalls in capacity in terms of facilities, manpower, and skills.
- o To create parameters for programming and detail planning of engineering, procurement, and production activities.
- o To provide the basis on which any eventual production of the product may be organized, including procurement dates for "long lead" material items.
- o To provide a means of communicating consistent information between the various technical and production functions.

1.2.4.3 Scope of Contract Build Strategy - The contract build strategy will examine in outline all aspects of the construction of the vessel, or vessels, concerned. The overall scope is defined most readily by reference to the typical list of contents given below and following. In practice these may vary from shipyard to shipyard depending on particular local circumstances. The overall structure may also vary, provided all the elements are included. Each element is discussed in later paragraphs of this chapter.

Build Strategy Document Content

1. Introduction
 - o details of vessel
 - o details of special features/requirements
2. Main Production Parameters
 - o key dates/planned production rate
 - o build location/launch condition
 - o productivity targets
 - o labor resource requirements
 - o potential bottlenecks
 - o subcontract requirements
3. Build Strategy: Hull
 - o hull subdivision
 - o erection sequence
 - o outline methods descriptions

4. Build Strategy: Machinery Spaces
 - o identification of installation zones
 - o installation sequence
 - o identification of outfit assemblies
 - o outline method descriptions
5. Build Strategy: Accommodation
 - o accommodation structure subdivision
 - o erection sequence
 - o identification of installation zones
 - o installation sequence
6. Planning Framework
 - o list of planning units
 - o building program
 - o interim product groups & work stations
 - o work station load analyses
7. Main Purchasing Dates
 - o high tensile steel
 - o mild steel plate
 - o steel shapes
 - o high cost/long lead time equipment
 - o pipe and fittings
 - o electrical cables

Although the scope has been defined as being wide enough to cover all aspects of ship constructions the level of detail used may vary. This will depend in particular upon the timing of the production of the build strategy.

The build strategy will always apply to a particular contract, and will be produced immediately after the contract is awarded. It can then serve as a basis for subsequent planning and design activities. At this time, the build strategy will be in sufficient detail to lead into those subsequent activities.

However, there is value in having at least some elements available earlier. A preliminary version of the build strategy may therefore be produced at any time during the preliminary design stage. Typically, the preliminary build strategy would accompany a bid to demonstrate how targets can be met and to show, for example, how a major new design feature would be undertaken in production. In its preliminary form the build strategy is an important input to the preliminary design; in its final form it guides the development of functional design into transition design.

Inputs to the contract build strategy include the following:

- o Design information, such as general arrangement plan, preliminary midship section, preliminary lines plan, bulkhead plans, preliminary machinery arrangement, outline specification.
- o Proposed construction rates.
- o Proposed productivity targets for key trades.
- o Details of key production facilities in document form.
- o Assembly analysis information for typical units.

1.2.4.4 Vessel Details - It is not uncommon for managers and supervisors in a shipbuilding company to be unaware of details of the ships to be constructed, but it can be beneficial to provide a note of the main features of the vessel. Particularly where supervisors work in remote work areas, away from the berth where the finished vessel takes shape, providing more information can be good for morale. The build strategy, which should have wide circulation, is a good medium for this.

Of greater significance is the need to identify special or unusual features of the vessel and to draw attention to these. The second part of the introductory chapter of the build strategy carries out this function. The shipbuilding policy documents and the ship specification provide essential inputs.

The features so identified may be unusual or novel aspects of the design, parts of a vessel requiring particularly high accuracy or elements of the ship beyond the normal capabilities of the shipyard. For each feature, the impact on the shipyard facilities must be assessed and an action proposed. At the build strategy stage, the action may not be finalized because some further evaluation or design is needed. What the build strategy is able to do is list the requirements for action, identify who should take action, and through planning determine when action must be taken. The fact that the need for action is noted in the build strategy does help to ensure that action is taken.

1.2.4.5 Main Production parameters - The second part of the contract build strategy document defines the main parameters which affect the production of the vessel. Necessary inputs to this definition process are shipbuilding policy documentation covering facilities and production rates, ship specification and general arrangement drawings, and strategic planning information.

Planned Production Rate: The capacity of the various elements of the production system, including at least the shipyard's capacity in man hours or tons, can be shown from historical data. Ideally, the production rates for various assemblies and installation activities will be available in some detail. In either case, the requirements imposed on the system can be calculated and compared with capacity, and bottlenecks can be identified.

Build Location: It is, of course, necessary to check that the vessel can be built on the proposed berth. Berth information should include any obstructions, water depth limitations, or other restrictions. Available crane capacity and outreach data are also essential. Once the vessel location has been decided upon, in conjunction with planning data on other vessels, any special requirements or restrictions can be identified and noted as requiring action.

Launch Conditions: Initial calculations should be made to ensure that no problems will arise. Calculations should take into account the shipyard's policy on installation of outfitting items prior to launch.

: A key date program will be compiled noting approximately 50 activities and covering events from contract signing to delivery. Examples of items included are order of long lead, high cost, materials, **design drawing approval by zone**, approval of building program, production start, keel laying, launch, and sea trials. The program will also be resourced at least with those trades likely to show an overload; subcontractors should also be shown.

Labor Resource Requirements: Assessments of productivity **targets, planned production rates,** and requirements must be compared with available resources. Decisions must be made about varying resources or the dates, if possible, to ensure that the overall contract program is achievable. Requirements for subcontractors, if any, can be generated from this analysis.

Potential Bottlenecks: These will have been identified during the assessment of production rates. It may be necessary to upgrade facilities, vary resource levels, or take other actions. Each bottleneck must be listed with the intended remedial action, and a completion date for the action.

Subcontract Requirements: When the assessment of contract requirements and the evaluation of the shipyard's ability to meet those requirements have been completed, some adjustments might be needed to balance the two. There will be some unavoidable mismatches between requirements and capabilities, and these need to be met by subcontract. Requirements for subcontract must be clearly stated and both the timing and potential sources identified. Any outstanding problems must be noted, with action for their resolution.

1.2.4.6 Build Strategy: Hull - In the third part of the build strategy document, the production of the ship's hull is considered.

Define Block Breakdown: The first task is to make preliminary weight calculations to help in determining the best subdivision of the hull. The cargo carrying part should be divided so as to give clean vertical breaks, with self-supporting blocks. If such blocks cannot be made using a block length approaching the maximum plate length that can be handled, then there is a shortfall in crane capacity for building the ship being analyzed. This will not stop the project from going forward, but will limit the overall performance potential. It may indicate a need for long term facilities development.

Erection Sequence: The next task is to determine the most appropriate erection sequence. Since the machinery spaces are usually the critical areas of high work content, most shipyards **achieving** high productivity and short building cycles start erection at the forward end of the machinery space. The implications of this must be noted for the build strategy and for the design process.

Initial Process Analysis - Steel and Outfit: When the hull blocks have been defined, a series of sketches or isometric drawings may be made of each block type which show how each erection block is further subdivided into subblocks and subassemblies. The sketches will be supported by outline method descriptions, covering both steel and outfit activities. Information given will include the block or subblock weight, overall dimensions, location of build, and orientation during building.

1.2.4.7 Build Strategy - Machinery Spaces - For a conventional cargo vessel, the breakdown into hull, machinery, and accommodation primary zones will be sufficient. For more complex vessels, more primary zones may be identified which have sufficient specialized features to require separate consideration in the build strategy. In all cases, the process will be similar.

Within the hull envelope, installation zones are identified, installation sequence considered and potential outfit assemblies identified. Given a detailed shipbuilding policy, much of the analysis will be standard procedures. The preliminary arrangement drawings will be a major input.

Identify Outfit Zones: In parallel with the block subdivision, the division of the hull into spaces will be completed so that post-erection outfitting may be organized into definable zones.

The machinery space breakdown must take account of the proposed outfitting method and the engine room arrangement; it is necessary to discuss this with the designers to find the best solution. The eventual breakdown will again be influenced by crane capacity but the main aim should be to design the machinery arrangement and block boundaries so that a substantial amount of outfitting can be completed on blocks prior to erection.

Installation Sequence: Analysis of each zone is needed to decide which elements of the outfit content can be installed at various stages of steel assembly and ship construction. The guiding principle is that installation work should be completed as early as possible, and in the most convenient location.

Identify Outfit Assemblies: The outfitting work will be examined in order to draw up a list of outfit assemblies which can be mounted on-block or mounted after erection. Outfit assemblies will be identified and a list made of the main components included in each. They will then be either linked with a steel block (pre-erection) or with a defined post-erection zone. Making each zone similar in work content should be the goal in defining post-erection zones.

1.2.4.8 Build Strategy - Accommodation - As with machinery spaces, more than one primary zone may be defined. The preliminary arrangement will be essential input, and should be in accordance with the shipbuilding policy of the company.

Subdivision: The subdivision into steel assemblies or blocks should facilitate the early installation of equipment and fittings, and make the best use of available craneage.

Erection Sequence: The building of the accommodation block, or the assembly of hull blocks with a high outfit content, must be related to the overall erection sequence. It may be necessary to accept less than optimal sequences in some steelwork areas to permit more outfit installation.

Identification of Installation Zones: As with machinery spaces, the accommodation area will be divided into zones for installation. The zones will be coordinated with the steel assemblies and blocks to ensure that maximum work content can be completed early.

Installation Sequence: Each zone will be analyzed to identify work to be completed at each stage of assembly and construction.

1.2.4.9 Planning Framework - From the analysis of the various zones of the vessel, a list of planning units can be developed. In conjunction with the key date plan and a type plan for the vessel type, if available, an overall building program can be developed.

List of Planning Units: From the previous analysis a list of all steel blocks, zones and installation activities can be developed. These are the planning units, which represent significant events in the building program, and which also provide the basis for all subsequent planning activities.

Building Program: If a type plan is available, it will form the basis for the building program. If not, then the sequence of erection and installation will be determined from the analysis of the vessel characteristics by primary zone and from shipyard practice. The key date plan will determine the overall time scale. The building program shows the start and finish date for each planning unit.

Interim Product Groups and Work Stations: The numbers of the various interim products will have been estimated from earlier analysis. For larger products such as flat panels, accurate numbers will be known. Each product group will be linked to specific work stations.

Work Station Load Analysis: The loading on work stations can be calculated using the estimates of numbers of interim products and the dates from the building program. This gives an indication of resource and facility imbalances and workstation utilization.

Engineering: The start dates for work on the various production elements will yield the required dates for production information. Knowing the dates will allow the engineering function to periodically provide the production function with the information it needs for its schedule. Key decision dates for the design can also be identified as can the need for possible design subcontractor assistance.

1.2.4.10 Main Purchasing Dates - The build program shows the dates on which the planning units must be completed. Using standard times for various manufacturing, assembly and installation activities, the delivery dates for vendor-furnished items and raw materials can be established. From these, ordering dates can be determined. Those items which might cause problems will vary according to the specific ship type and building program. Typical areas to be highlighted in the build strategy document are listed below.

High Tensile Steel: If the vessel requires high tensile or other special steel, the order date must be established. It also must be definitely established that the steel is available and can be delivered on schedule.

Mild Steel: For mild steel and other materials, the overall purchasing program must be established.

Shapes: Any unusual shapes must be identified, potential delivery problems highlighted, and solutions proposed.

High Cost and Long Lead Time Equipment: The number and value of these items will depend of course on the vessel specification. Whatever the case, the purchasing program must be integrated with the build program. It must also conform to any changes in practice, for example to decisions regarding the extent of advanced outfitting to be applied to the vessel.

1.2.4.11 Conclusion - The formal preparation of the build strategy ensures that all significant features of the contract are considered early enough for problem areas and bottlenecks to be identified and effectively overcome. It ensures that the company shipbuilding policy is applied to the contract and that all relevant departments contribute to the planning of the construction of the vessel. The distribution of the document ensures both that key decisions are communicated throughout the shipyard and that everyone is working to a common plan.

The build strategy becomes the basis for all decision-making related to the timely completion of the contract from basic design through production to commissioning and delivery. A formal approach to build strategy (and the production of build strategy documentation) provides a means of planning for change from contract to contract within the framework of the shipbuilding policy.

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